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Another Way to Skin a Cat:
Argument-Driven Inquiry in the Human Anatomy Laboratory

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Another Way to Skin a Cat:
Argument-Driven Inquiry in the Human Anatomy Laboratory

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Dedication

This dissertation is dedicated to my beautiful bride, Grace. Without your tremendous care, tireless efforts, sacrifices, and patience during my numerous rants, I would not have finished. Thank you for not letting me set this whole thing on fire.

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This dissertation is the culmination of a three-year project, which concludes twelve years in higher education. None of it would have been possible without the support and sacrifices of my parents, Charles and Tammie. God opened the door, and you made it possible for me to walk through it. Every student I've helped, and everything I've touched will always be because of you.

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Abstract

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The demand for healthcare professionals is expected to grow faster than any other industry through 2028. Fundamental to the training and practice of healthcare professionals is human anatomy. However, human anatomy courses experienced substantial declines in time and resources in recent years; reducing anatomical studies to rote memorization. As a result, human anatomy labs often lack best practices in science education, which foster the development of the scientific proficiency that supports the deep learning and reasoning students will need for the high levels of problem-solving in healthcare. PURPOSE: The purpose of this dissertation was to explore the potential for implementing the novel laboratory-teaching framework of Argument-Driven Inquiry (ADI) in the human anatomy laboratory. The research questions related to the feasibility of ADI in anatomy, and the impact that varying levels of ADI had on students' knowledge, reasoning, and perceptions. METHODS: This dissertation conducted three studies. Participants in Studies I and II were 126 and 215 undergraduates respectively. Participants in Study III were 108 first-year medical students. Study I implemented a one-week modified ADI lab in one course section. The subsequent lab exam assessed differences in factual learning compared to the standard labs. Study II implemented a modified ADI lab protocol for the final four weeks of a human anatomy course; using the previous semester's standard protocols as a control group. Factual learning and application reasoning were assessed on the lab exams at the mid-term and final. Study III conducted a medical procedure learning event and assessed factual knowledge changes as well as student perceptions in a pre- and post-test survey. ANALYSIS: For Study I, a 3-way ANOVA tested for mean differences in factual knowledge between lab groups. For Study II, a 3 x 2 mixed factorial MANOVA with repeated measures on the second factor was conducted to test for mean differences in factual knowledge and application reasoning. For Study III, separate one-way repeated-measures ANOVAs tested for mean differences between pre- and post-test factual knowledge and student perceptions. RESULTS: Study I showed no difference in factual knowledge between the modified Argument-driven labs compared to the standard labs. Study II showed no difference in factual knowledge between the intervention and control groups. The intervention group scored significantly higher on the application reasoning assessment. Study III showed no difference between pre- and post-test factual knowledge, and students perceived the medical procedure lab more positively than the standard dissection lab. DISCUSSION: Argument-driven Inquiry is a novel approach that provides a theoretically sound framework for science education. While students report greater engagement, and show improvements in reasoning, there are implementation challenges that restrict its effectiveness at improving factual knowledge and reasoning for a large portion of students. Further research is needed to better understand the factors that allow for more effective implementation, which will allow the impact of ADI in anatomy to be tested in a more robust manner.

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CHAPTER I: INTRODUCTION

The U.S. Bureau of Labor Statistics projects the healthcare industry will add more jobs than any other occupational group through 2028. The driving force behind this 19% increase is a combination of factors related to an aging population as well as federal reforms impacting the number of individuals capable of gaining access to health insurance (bls.gov). Institutions of higher education and professional schools bear much of the training responsibility for developing this workforce. This preparation invariably includes a heavy dose of coursework in the biological and physical sciences (collectively known as the 'natural sciences') as both pre-requisites for matriculation and as advanced exposure to the governing mechanisms that contribute to health and disease (Woods, 2007).

The prominence of the basic sciences in the preparation of future healthcare practitioners arises from qualities that cut across domains. For example, the biological sciences form the backbone to organize, describe, and explain the natural phenomena related to health and disease (Woods, 2007; McCrorie, 2000). The natural sciences coursework provides structure for cognitive and procedural pathways that support learning for comprehension and problem-solving (Woods, Brooks, & Norman, 2007). Additionally, the sciences provide opportunities to engage in the actual practices of clinicians (Sampson & Gleim, 2009).

Typically, science courses provide opportunity for laboratory-based, experiential learning. According to the National Research Council's report on secondary school sciences, laboratory activities should rely on inquiry, incorporate reading, writing, and discussions, and allow for the generation and critique of arguments (NRC, 2005). However, post-secondary science labs often fall into two learning pitfalls: being demonstrative or being prescriptive. First, labs can be solely a demonstration of content (e.g., a lab activity demonstrating the heart rate's linear response to increasing physical workloads). During the lab, a participant runs on a treadmill at increasing speeds while attached to a heart rate monitor. The students will see the heart rate increase in real-time and can verify the validity of the concept in which greater physical demands drive increased blood flow. However, the lab fails to make space for identifying phenomena (feeling their heart rate when running, but not during walking), developing research questions or testable hypotheses (does hydration impact heart rate? Does heart rate respond differently under running vs. cycling?), or designing experimental protocols (older vs. younger participants). While observational labs can provide valuable exposure to concepts and procedures (e.g., data collection, participant safety, etc.), the observational laboratory activity fails to foster authentic scientific reasoning and experiences. It is tantamount to a person watching a construction site but never receiving the experience of building. Efforts to involve students in the scientific process while maintaining classroom efficiency and curricular objectives tend to produce highly structured labs, which are cognitively and procedurally prescriptive.

Secondly, labs can be prescriptive; preventing students from taking ownership of their learning. Prescriptive labs provide instructions that explicitly direct student activities and cognitions, thereby eliminating or restricting opportunities for students to engage in the creative process of scientific work. According to the social-constructivism theory, the process of learning occurs during interactions with others (Palinscar, 1998; Vygotsky, 1978). These interactions allow information and cognitive processes (e.g., schemata formation, heuristics) to be recalled, organized, elaborated, and revised to promote "meaning making" (Bruner, 1990). In the prescriptive labs, the students may appear to be engaging in science. However, the activity lacks space for self-directed discovery, problem-solving, or many of the cognitions necessary for meaningful learning. Students do not receive time to ask questions such as, “Why would this procedure lead to this outcome?” “What mechanisms may contribute to the response we see?” “How could we test for alternative mechanisms?” Procedurally, prescriptive labs funnel students towards completing a checklist or recipe without requiring constructive interactions with others. Historically, the human anatomy laboratory has experienced all of these learning pitfalls.

Human anatomy is the study of form and function in the living body and it is a bedrock course in many of the undergraduate and health professions programs (Blits, 1999). As such, human anatomy is a requirement for many undergraduate degree programs and a pre-requisite for graduate schools of health professions. Invariably, anatomy courses form a large component of early training for all healthcare professions (Paalman, 2000). Despite its historically lofty position in life science education, the quantity and quality of anatomy education has declined in recent decades (Ridenberg & Laitman, 2002; Bergman, Van Der Vleuten, & Scherpbier, 2011; Mitchell & Batty, 2009; Bockers et al., 2010). Reasons for these changes include curricular prioritization shifts, changes in student-learning, shortening of pre-clinical education, and a devaluing of excellent teaching. These challenges are less likely to impact lectures, as the content of anatomy is consistent over time. Instead, the challenges are of primary concern in the hands-on, experiential anatomy lab.

Among the challenges facing anatomical teaching are the varying approaches to laboratory learning. Dissection (using tools to remove and reveal internal structures), considered the hallmark of the biological science lab, can be performed on human cadavers or animal substitutes (e.g. cats). They can be student-lead or replaced with prosections (dissections completed by instructors that reveal structures for students to review at a later time). Anatomy programs without dissection, either as a curricular decision or due to a lack of access, rely on electronic media, texts, and 3D models to represent the human form. Regardless of the laboratory approach, the primary shortcoming of anatomy courses is the tendency to emphasize a bulimic learning style. Anatomy is heavily dependent on lower-level cognitive tasks such as memorization, identification, and description (Bloom, 1956). The primary inquiries are “what is this?” and “what does it do?” It is understandable that courses take this road, given the enormous volume of factual knowledge in anatomical study, and its historical underpinnings as a taxonomic science. However, given its foundational curricular status across numerous fields, the human anatomy laboratory is a potentially-powerful early entry-point for sparking and supporting scientific reasoning in students interested in healthcare fields (Darda, 2010; Older, 2004). Given the near universal, basic approach to the anatomy lab, it is ripe for modification to achieve these higher goals and any inclusion of higher order learning would represent a significant movement forward.

As a response to the NRC’s 2005 recommendations, Argument-Driven Inquiry has been developed as a flexible model to structure meaningful laboratory learning activities (Sampson & Gleim, 2009). The ADI model structures inquiry in the form of argumentation where students generate and support an explanation for a research question. As such, it is geared to improve both scientific literacy and proficiency. To develop their arguments, students in ADI carry out the processes of actual scientists: generate hypotheses, develop and implement investigations, gather and analyze data, communicate and justify ideas in a group-oriented argumentation session, write reports, and engage in peer-review (Sampson & Gleim, 2009). ADI labs are designed with the following eight stages:

1. *The* ***identification*** *of a task by the classroom teacher that creates a desire for the students to make sense of a phenomenon or to resolve a problem*
2. *A laboratory-based experience where small groups of students have an opportunity to* ***generate or analyze data*** *using appropriate tools*
3. The production of a **tentative argument** that articulates and justifies an explanation on a medium that can be seen by others
4. *An* ***argumentation session*** *where groups share their arguments and then critique and refine their explanations*
5. *A* ***written investigation report*** *generated by individual students that explains the goal of the investigation, the method used, and provides a well-reasoned argument*
6. *A double-blind* ***peer review of these reports*** *to ensure quality and to generate valuable feedback for the individual authors*
7. *A subsequent* ***revision*** *of the report based on review feedback*
8. *An explicit and* ***reflective discussion*** *about the inquiry* (Sampson & Gleim, 2009).

Among the benefits of ADI are its allowance for self-directed learning, engagement in generating, evaluating, and modifying ideas and explanations, and it provides a framework for interpersonal interactions that promote elaborations in knowledge, skills, and attitudes. That is, rather than students following a recipe with one answer – they are engaged in the practice of science and the process of interactively constructing a deeper understanding. Finally, ADI's flexibility allows for its application and integration across domains within and outside of the sciences (Sampson & Gleim, 2009). The first two studies of this dissertation will investigate the application of the ADI model to undergraduate anatomical education.

ADI provides a robust framework for learning domain-specific content through the general practices of building scientific literacy. Health professions schools bear the responsibility of preparing future clinicians for careers heavily-reliant on integrating content knowledge throughout reasoning-based problem-solving (Campbell, 1987; Miller et al., 2002). To this end, the human cadaver provides a medium to teach medical students to engage in integrating anatomical knowledge with clinical practice through the use of medical procedures. Clinical procedures provide a scaffolding to support the organization and application of anatomical knowledge; allowing facts to become practical (Jolly & McDonald, 1989; Kovacs, 1997). Learning procedures is also a novel form of vertical integration, the reciprocal reinforcing interaction between foundational biomedical sciences and clinical practices (Brauer & Ferguson, 2014). This integration is especially relevant in the novel problem-solving process physicians undergo (albeit more-so in the early years of practice) when conducting differential diagnoses and treatment plans (Vink et al., 2015).

Unfortunately, the value derived from integrating anatomical learning with medical procedures is absent from first-year anatomy courses which comprise the majority of explicit anatomical education in medical schools. Studies have used cadavers to demonstrate surgical procedures (Fitzpatrick et al., 2001; Are et al., 2009) or non-surgical procedures such as placing a chest tube to treat a collapsed lung (Wilson & Nava, 2010). While these studies did not evaluate students' factual or clinical knowledge, they found the students highly-favored the exposure to authentic practices, and gauged their anatomical studies as being more relevant.

The architecture of the gross anatomy lab within health professions schools is often a large space with students standing around human cadaver tables (approximately 7’ x 2.5’). Instructors rotate throughout the lab, providing dissection technique, answering questions, and assisting in dissecting difficult structures. The students proceed to follow a dissector manual that directs the focus and order of dissection and identification. While instructor-student interactions may vary between institutions, there is a general culture of supervised exploration. However, dialogue that generates meaningful links and elaboration within the learners’ knowledge are rare and occur differentially by table and may contribute to reports that indicate, despite anatomy’s clinical value, medical students and early-career physicians do not possess sufficient clinical anatomical knowledge (Waterston & Stewart, 2005; McKeown et al., 2003; Gupta, et al., 2008).

Reflecting the growing belief that medical students are not receiving sufficient training in anatomy, Bergman and colleagues’ reviews (2011, 2013) identified trends of impaired student learning but found few articles that empirically evaluated anatomical knowledge. Despite this, the authors concluded that anatomy lags other basic sciences in practices that improve knowledge acquisition and application (learning in context, exposure to clinical practices, and vertical integration). While senior medical school students strongly believe anatomy to be relevant in their clinical practice (Moxham & Plaisant, 2007), a study of Australian medical students reported that 65% described their medical school’s emphasis on anatomy as ‘far too little’ or ‘too little,’ and only 40% felt they would have sufficient anatomical knowledge to practice competently (Mitchell & Batty, 2009). The gross anatomy lab provides an ideal location for intervening on the anatomical integration gap because students have the ability to work through clinical procedures in a way that contributes to the development and retention of professionally-relevant knowledge and skills (Dangerfield et al., 2000; Fasel et al., 2005; Raftery, 2007).

The cadaver-based instructional activities may satisfy the needs for learning in context, exposure to clinical practices, and the vertical integration of biomedical sciences throughout clinical reasoning. While it seems intuitive that doing what clinicians do would improve learning anatomy, there are no studies examining procedure-based learning activities in first-year medical curricula; where the main exposure to anatomy occurs for medical students. Additionally, these types of activities are not immune to the pitfalls common to any scientific learning endeavor, and can become procedurally-focused to the detriment of reasoning and content acquisition. As ADI promotes the development of scientific reasoning through engaging laboratory content, it may be an effective guide for cadaver-based medical procedure learning. However, teaching anatomy through medical procedures has not been demonstrated in the literature, and the application of ADI within anatomy is also a substantial deviation from traditional and modern pedagogical approaches. Therefore, the third study of this dissertation assessed the feasibility and potential impact of cadaver-based procedural learning, and how to appropriately support the implementation of ADI.

STUDY AIMS

Aim 1: To pilot a limited version of ADI through a clinically-oriented, team-based, and argument-driven approach to learning in an undergraduate human anatomy laboratory to ensure that there was no detriments to student performance. This aim was the result of a local concern for the potential for ADI to diminish course content exposure, thereby hindering students' academic performance.

Aim 2: To assess the feasibility of implementing Argument-Driven Inquiry in human anatomy through quantitatively measuring learning outcomes on lower- and higher-level cognitive tasks in an undergraduate human anatomy laboratory following standard practices vs. select components of the ADI model. It was hypothesized that that students would achieve higher scores on fact-based and clinical application exam items following the argument-driven labs compared to the standard practices labs.

Aim 3: To explore the feasibility of conducting a high-fidelity medical procedure learning activity to inform future implementation of the Argument-Driven Inquiry model within a first-year medical school gross anatomy dissection course.

RESEARCH PURPOSE

The purpose of this dissertation was to explore the feasibility of applying and implementing a novel laboratory learning methodology (Argument-Driven Inquiry) to human anatomy across different institutional settings. Understanding the objective impacts and logistical considerations of these experiences served as foundational research regarding a substantial shift in the approach to teaching anatomy that may support the educational community in developing anatomy laboratories that reflect best practices in science education.

DEFINITION OF TERMS

- **Basic Sciences –** coursework considered fundamental to understanding the development and treatment of disease (anatomy, physiology, biochemistry, pathology, cell biology, immunology, genetics, etc.)

- **Argumentation –** The development, support, communication, and revision of ideas or positions.
- **Cadaver –** A deceased human body donated for educational purposes.
- **Clinical Reasoning –** The application of inductive and deductive logic to the confluence of data connected to an individual that allows a clinician to arrive at a diagnosis of disease (or rule out disease).
- **Science Proficiency –** The designation given for the four strands of abilities and practices essential to effective scientific reasoning. The four strands are 1) knowing, using, and interpreting scientific explanations of the natural world; 2) generating and evaluating evidence and explanations; 3) understanding the nature and development of scientific knowledge; 4) participating productively in scientific practices and discourse.
- **Dissection –** The procedural approach of using tools to reveal internal anatomical structures.
- **Prosection –** A dissection completed in advance by an instructor or expert that reveals internal anatomical structures for students to review at a later time.
- **Anatomy –** The science and nomenclature identifying and describing the human body, its structures, organization, and functions.
- **Gross anatomy –** The science and nomenclature describing the structures, organization, and functions of the human body that is visible with the naked eye.
- **Taxonomy –** The science of naming, categorizing, and organizing.
- **Physiology –** The science of the molecular mechanisms within the human body that drive the function of cells, tissues, and organ systems.

- **Health profession schools –** In the United States, the graduate education schools that train individuals for careers as health professionals (physicians, physical therapists, nurses, etc.)
- **Medical procedure –** Activities performed by medical professionals in the diagnosis and management of potential diseases in patients.
- **Resident –** Licensed physicians that have finished medical school, but are in supervised training programs within patient-care settings.
- **T-test –** A statistical test that compares two averages (means) and indicates if they are statistically different from each other.
- **Curriculum Integration** – The level to which the designed learning progression and environment interacts and collaborates within a course or institution.
- **Critical Thinking –** The intellectually disciplined process of actively and skillfully conceptualizing, applying, analyzing, synthesizing, and/or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action.
- **Repeated Measures Analysis of Variance (RM-ANOVA) –** An omnibus statistical test applied to detect any overall differences between means for related, not independent groups. Also referred to as a "within-subjects ANOVA" or "ANOVA for correlated samples."

DELIMITATIONS

The results of this dissertation were delimited to undergraduate (studies 1 and 2) and medical (Study III) students at highly selective schools. While there is evidence that the approaches used in this dissertation are likely to provide a greater benefit to students from less-selective schools, it is possible that they require different teaching strategies to support success and would require a separate study. The results are further deliminated to the study of anatomy and cannot be applied to other life or health science courses. Finally, they are deliminated to the study of the musculoskeletal system (studies 1 and 2) as well as anatomy of the neck (Study III) and cannot be applied to other aspects of gross anatomy labs.

Generalizing these studies may be limited as the time and resources available to the undergraduates and medical students may not represent the time and resources at other institutions. The medical student sample may not be representative of the larger population as the institution recruits students with a strong history of academic performance. As such, the impact of the medical intervention may be limited, as the scores may experience a ceiling effect due to strong pre-laboratory preparations.

Learning outcomes were delimited to quantitative performance on academic assessments. The literature in learning interventions tends to focus on student and instructor perceptions of learning, but few provide objective assessments at multiple levels of cognitive demand.

LIMITATIONS

The dissertation used a quasi-experimental methodology in which laboratory sections were assigned to condition (Study I and 2) and a pre-experimental one-group pre-test/post-test method (Study III). This opened a number of threats to internal validity. For example, in Study II, condition was not randomly assigned but was assigned consecutively (control first, then intervention). This opened the threats of calendar-associated differences (e.g., the length and location of academic breaks) between semesters. Sequential groups may have received exposures to different laboratory instructors or the natural maturation and development of the same instructors. The composition (age, sex, motivation, aptitude, etc.) of the groups may vary as well. This is the nature of higher education as it does not easily allow for random assignment to learning strategies. Despite this, the consistency of performance over time in these anatomy labs allowed some confidence in the impact of the intervention when it was associated with change from earlier semesters. Additionally, all assessment of learning outcomes in the undergraduate lab were measured with delay to coincide with the laboratory exam schedule required by the larger course. This delay may have diminish group differences as the students had opportunities to independently enhance their learning in preparation for the exam. In the first-year medical anatomy lab, the follow-up assessment shared the same limitation.

The learning outcomes for the undergraduate students were not measured in an immediate pre-post methodology due to the larger course using existing pre-post quizzes. These quizzes were not incorporated for two reasons. First, they were accessible online and had the potential for confounding factors such as using the textbook or an internet search to answer. Second, the questions were solely lower level cognitive tasks that did not demonstrate sufficient variability to provide a fair test of the ADI approach.

SIGNIFICANCE OF STUDY

This dissertation was the first to apply an argument-driven approach to learning of human anatomy. As such, it provides a basis from which to explore a fundamental shift in the teaching of anatomy. Additionally, this dissertation contributed objective evidence to the growing literature surrounding learning through high-fidelity medical procedures. This is likely to be more engaging for students in the pre-health professions and in medical school. It is also likely to support other instruction across the curriculum. This reflects a larger effort to better integrate instruction across content areas to improve student learning and anatomy has the potential to serve as a foundational course to achieve these ends. Given the fundamental nature of anatomy within the preparation and practice of future healthcare professionals, there is a strong need for approaches to laboratory learning that promote the knowledge, skills, and attitudes that promote life-long learning, problem-solving, and effective communication.

CHAPTER II: LITERATURE REVIEW

ANATOMY EDUCATION

According to the National Board of Medical Examiners (NBME), there are 13 biomedical sciences fundamental to the practice of medicine in the U.S. (USMLE.org); the oldest and most established of which is human anatomy. Clinicians rely upon anatomical knowledge for examinations, clinical reasoning, diagnoses, interventions, and communication (Prince et al., 2005; Turney, 2007); making anatomy indispensable in medical education. Since the turn on the 20th century, the time dedicated to the study of anatomy in health professions schools decreased by half, and in some cases by two thirds (Collins et al., 1994; Utting and Willan, 1995; Cottam, 1999; Fasel et al., 1999; Holla et al., 1999; Leong, 1999; Dangerfield et al., 2000; Pryde & Black, 2005). Due to its bedrock status, the compression and reform of anatomy courses have prompted a wealth of literature extolling its value, what students and physicians know, what they should know, and the efficacies of differing learning modalities.

The resulting narrative consists of three themes. First, the basic sciences, and anatomy specifically, provide the learner with a meaningful framework for understanding, recalling, and applying knowledge within the complex problem-solving necessary for clinical practice. Second, anatomy education has radically changed since the early 20th century; resulting in courses and pedagogies that vary as much as the bodies of which they teach. Third, there is a growing area of research indicating that medical students and junior physicians lack the applied anatomical knowledge necessary for their roles in the healthcare system. Acquiring, understanding, and integrating anatomy into clinical reasoning require time and resources that rarely exist in the present curricular paradigm. As a result, anatomy education has been reduced to its most fundamental units: the structures of the human body and their functions. Under this framework, the emphasis of educational research on determining the most effective, yet efficient, methods of facilitating acquisition and retention of anatomical content is understandable. Unfortunately, prioritizing the tremendous content volume in such a narrow timespan reinforces surface-level learning; a flawed approach to preparing future healthcare providers for the complex, reasoning-based problem-solving in which they will work.

In order to explore the hypothesis that students would learn better should they engage anatomy in the way clinicians use it, this review evaluates articles related to general anatomy teaching and learning, as well as varying learning interventions in classroom settings. As the bulk of anatomy education tends to focus on modalities that improve anatomical knowledge through differential visualization media, it appears that courses are failing to provide a significant cognitive demand in an authentic and contextually-relevant manner to support developing clinical reasoning. In light of such tendencies, this review considered the literature covering two approaches that emphasize learning in context of the fundamental practices students will encounter as professionals: Cadaver-Based Medical Procedures and Argument-Driven Inquiry.

Do trainees know enough?

In a study on student clinical anatomy knowledge, 162 senior clinicians from 6 specialties who oversee medical students and recent graduates were asked, (1) “Do you think that medical students coming through your department have an adequate knowledge of general topographical anatomy?” and (2) “With reference to today’s medical graduates, do you think their level of knowledge of clinically relevant anatomy is too little / adequate / excessive to make them safe medical practitioners?" (Waterston and Stewart, 2005). Results found that 64% of responders indicated that current students had inadequate knowledge. The 2 specialties with the strongest ties to anatomy (radiology and surgery) answered "inadequate" at 82% and 72% respectively. In addition, 61% of the responders indicated that the clinical anatomy knowledge of recently-graduated physicians knowledge was "too little" for safe practice. It is not surprising that radiology (91%) garnered the greatest criticism as this is the specialty that most requires anatomical knowledge. However, the next two specialties that most frequently provided this response were anesthesiology (68%), and surgery (64%). Thus, the lack of knowledge appears to be a general concern. Finally, nearly all of the respondents indicated that the students' lack of anatomical knowledge was hindering their learning for clinical examination and diagnosis. The authors also connected this perspective with previous research suggesting that the increasing trend in malpractice litigation may be the result of 'anatomical ignorance' (Goodwin, 2000; Cahill et al., 2000; Ellis, 2002; Brennan & Leap, 2009).

To assess knowledge more objectively, Prince and colleagues (2005) developed a mixed item exam (multiple choice, free response, true/false) with 107 clinically-relevant questions centered on 13 patient cases. The exam was administered to 348 medical students from 8 medical schools before the beginning of their clerkships, and the overall score was calculated as the percentage of correct answers. The students' mean score for the exam was 53.2%, when an independent panel of judges from the clinicians group suggested that the criterion for a passing score should be 54.3% for the exam. Using the cut-off established by the clinicians, 57.5% of the medical students would have failed the exam. The authors repeated this process with judging panels comprised of anatomists, recent medical graduates, and students at the same level of training with similar results. Naturally, the question arises as to when medical students gain the necessary clinical-anatomy for safe practice.

Similarly, Gupta and colleagues (2008) noted that the compression of anatomical study in medical curricula was forcing students to learn the essentials of clinical practice, especially in surgery, later in their training - even after graduating from medical school. To demonstrate this, the authors developed a multiple-choice questionnaire covering 15 areas of anatomical knowledge essential to clinical practice:

1. Clinical examination of the heart, chest, and nervous system
2. Interpretation of common radiographs
3. Anatomy of common fractures
4. Anatomy of clinical procedures

The survey was administered to 128 junior physicians with less than 6 years of professional practice. The results showed that increasing levels of clinical training corresponded to higher scores and that the first-year physicians significantly lagged behind their near-peer colleagues by 6-10 percentage points. It could be further argued that the group differences may have been more pronounced on an assessment that was not multiple-choice. The authors concluded that the results confirmed their hypothesis that a significant portion of clinical anatomy knowledge related to basic medical practices was being learned after medical school.

A survey of 610 Australian medical students reported that 65% believed their respective institution insufficiently emphasized anatomy, and 60% did not feel they would have adequate anatomy knowledge for competent practice. Similar results show that 67% of New Zealand medical students believed they did not know enough anatomy for safe medical practice (Insull, Kejriwal, & Blyth, 2006). A study of recent medical school graduates in the U.K. also showed that 53% of those entering surgical training, and 44% of those entering non-surgical careers believed they did not receive sufficient anatomy teaching (Fitzgerald et al., 2008). There are many unknowns in anatomy education, and debates abound regarding best practices, course hours, cadavers, philosophies, and professional futures. All the while, medical students and junior physicians perceive their training and knowledge in anatomy to be insufficient for safe clinical practice; a perception supported by assessments from supervising clinicians and tests of clinical anatomy utilization.

There is no doubt that anatomy education has experienced wholesale changes since the 1980's (Collins et al., 1994; Utting and Willan, 1995; Cottam, 1999; Fasel et al., 1999; Holla et al., 1999; Leong, 1999; Dangerfield et al., 2000; Pryde & Black, 2005). According to data from the Federation of State Medical Boards and the American Association of Medical Colleges, these shifts in anatomy education potentially impacted the training of 70% of actively-licensed physicians in the U.S (Young et al., 2017; AAMC, 2015). With such an extensive influence, it is important to consider these educational trends and the impact they have on learning in a foundational medical science.

Anatomy education over the years

There appear to be three major forces driving the global restructure of medical education (Leung, et al., 2006). First, since the 1960's there has been a rapid expansion of biomedical knowledge required of physicians with no change in training time. Second, the nature and logistics of professional practice are shifting quickly. Lastly, there has been an emergence of new health problems and greater understanding of associations with behavioral and environmental risk factors. Each of these has added to the medical curriculum that necessitate cuts elsewhere. As the early years of medical education often receive the moniker of "preclinical years" designated to prepare students for the clinical rotations, this phase was the preferred location for change in the curriculum. Since anatomy possessed an enormous percentage of the time, it was only natural for it to be the largest casualty in curricular evolution. For example, anatomy's dedicated space declined from 550 hours at the turn of the 20th century to 300 hours in the 1950's, and now averages approximately 165 hours (Ghosh, 2015) - a 70% reduction in less than 100 years!

This shift is born out in a series of surveys between 1994 and 2009 identifying trends that programs had reduced hours for anatomy and relied less on classically-trained anatomists/graduate students to teach, and incorporated less content, lectures, and memorization in their courses (Collins et al., 1994; Drake et al., 2002; Heylings et al., 2002; Drake et al., 2009). Course directors and department chairs were asked about their programs. Only 13% of the schools reported retention of the "traditionalist" (lecture + regional dissection) course format. While 98% continued using lecture as a form of non-lab teaching, only 39% indicated that lectures were the only method used outside the dissection lab. The implementation of small-group learning (problem-based learning, computer-assisted learning) was present in 62% of schools, with another 20% reporting presently piloting alternative pedagogies in their anatomy curricula.

Nearly a quarter of the schools in the UK have reduced or eliminated the dissection component of the gross anatomy lab in favor of alternatives (Heylings, et al., 2002), with similar reduction in the US (Drake, et al., 2002, 2009). In addition, there has been a shift away from hands-on, laboratory experiences. It is no wonder that some authors echo the unease among faculty described by Collins and colleagues (1994) indicating that the reduction of anatomy will hinder physician development, biomedical research, and ultimately patient care (Paalman, 2000; Older, 2004). However, not all authors agree with this perspective and see the dethroning of anatomy as a welcome opportunity to reform an outdated science (McLachlan, 2004; McLachlan & Patten, 2006; Collins, 2008).

Perspectives on the evolution of anatomy education

The contention between these schools of thought tend to center on the cadaver dissection lab. According to Collins (2008), dissection is an inefficient use of time that restricts the anatomy course from being seen as a component of continuous learning throughout medical training. As such, the medical school ensures mastery of fundamental principles and core knowledge of anatomy necessary to start clinical practice and post-graduate training accounts for proficiency in anatomy relevant and specific to its specialty. McLachlan and Patten (2006) also advocate for leaving dissection in the past; citing its failure to provide students with an authentic learning experience for their practice as clinicians. Their solution is to develop curricula around "living anatomy," which promotes the exclusive use of exploring anatomy through examining living people and medical imaging (MRI, x-ray, etc.). Reviews of anatomy education tend to favor a more moderate perspective by suggesting a multimodal approach that adds dissection/prosection, interactive multimedia, and procedural anatomy (Sugand, Abrahams, & Khurana, 2010; Sawant & Rizvi, 2015). According to McLachlan and Patten (2006), the question that would simplify anatomy education is, "which method of teaching about the structure of the body produces the most effective clinicians?" The authors admit to the inherent difficulty of answering such a question but urge the academic community to remember the bigger picture in anatomy education: preparing future clinicians. While some educators see the international shifts in anatomy education as a dichotomous battle between dissection and its alternatives, most authors step out of the debate, and ask a simpler, question: “what methodology best promotes learning in anatomy?

Best practices according to anatomists

According to an attitude survey of 112 professional anatomists from 13 European institutions of higher learning conducted by Patel and Moxham (2006), 90% favored educational change, and 98% believed gross anatomy had an important role in clinical medicine. Nearly 70% preferred cadaveric dissection relative to other methods of teaching, citing its ability to facilitate a range of course objectives. The authors ranked the teaching methods according to respondents’ preferences and found the following:

1. Practical lessons using cadaveric dissection by students
2. Practical lessons using prosection
3. Living and radiological anatomy
4. Computer-aided learning
5. Didactic teaching alone
6. Use of models

In a follow-up study (Patel and Moxham, 2008) the 112 anatomists rated the 6 teaching methods according to 12 course aims and assessed the methods individually according to each objective to assign a “fitness for purpose.” The anatomists rated dissection first on 9 of the 12 learning objectives. Additionally, dissection alone received a rating of “excellent” for fitness on any objective. The authors were surprised to find that none of the teaching methods achieved a “good” or “excellent” fit for achieving the objective of providing background for other basic sciences.

Best practices according to students

Surveys representing 1,777 medical students around the world sought to capture where students stand on the way anatomy should be taught in medical schools (Kerby, Shukur, & Shalhoub, 2011; Davis et al., 2014; Mitchell & Batty, 2009; and Marom & Tarrasch, 2015). Students strongly agree that cadaveric dissection should be the centerpiece of anatomy education (Marom & Tarrasch, 2015) as it is essential to understanding (Davis et al., 2014). Similar to Patel and Moxham (2006, 2008), Kerbey, Shukur, and Shalhoub (2011) conducted a survey of medical students who ranked dissection and prosection in the top 2 over 70% of the time. Dissection was the only teaching method to receive a “fit for purpose” score of “excellent,” and in a third of the objectives, dissection alone received the designation of “good.” Other trends across studies included a greater preference for clinical relevance, small group teaching, and medical imaging.

Why don’t they know enough?

According to a set of reviews by Bergman, et al., (2011; 2013), there are 8 commonly-cited detractors that may be hindering adequate anatomical knowledge.

1. Anatomy is increasingly taught by non-medically qualified teachers
2. The absence of a core anatomy curriculum
3. Decreased use of dissection as a teaching tool
4. Anatomy is not taught in context
5. Integrated curricula (problem-based learning or systems-based)
6. The way anatomical knowledge is assessed
7. Decrease in anatomy teaching time
8. Neglect of vertical integration in anatomy teaching

The authors conclude that the literature either lacks sufficient studies examining how most of the potential barriers impact content acquisition and retention, or the studies do not achieve sufficient internal validity; making it difficult to determine the claim’s accuracy. While a definitive cause may be challenging, the literature does provide reasonable amount of evidence to suggest that curricular changes are contributing to insufficient clinical anatomy proficiency.

Possibly the largest set of arguments around anatomical knowledge centers on curricular change and decreased dissection time (Parker, 2002; Older, 2004; Paalman, 2000; Rizzolo & Stewart, 2006). A study on the impact of a massive curricular shift in anatomy administered surface anatomy assessments to a cross-section of students representing varying levels of exposure to the old, traditional and new, compressed curricula (McKeown et al., 2003). The more advanced students achieved higher scores and final-year students from the traditional system far outperformed all groups. Similar finding show that anatomy demonstrators, junior physicians with 2-4 years of clinical experience who take a 6-month sabbatical to teach anatomy to medical students, may experience an accelerated progression of competence in clinical anatomy typically seen with additional years of specialist training (Gupta et al., 2008). Additional evidence for this claim comes from results of a 3-year study showing the first-time pass rate of anatomy demonstrators in the applied basic science component of the Royal College of Surgeons Fellowship exam was 75% vs. the overall first-time pass rate of 37% (Miller & Neal, 1994).

A study comparing curriculum impact on anatomy knowledge asked students from all 8 Dutch medical schools, representing PBL or traditional learning, to complete a clinical anatomy assessment (Prince et al., 2003). The top-performing school (traditional) scored significantly higher than all other schools while 2nd-7th schools showed no significant differences. The authors noted the top school devoted twice as much time to anatomy as the other schools, combining traditional dissection and clinical context throughout the course, though not in an integrated or problem-based manner. In a randomized-control trial, traditionally-trained students significantly outperformed PBL students on a True/False anatomy assessment (Hinduja et al., 2005). Prince et al. (2003) remarks that when PBL vs. non-PBL studies find knowledge differences in other basic sciences, the data tends to favor non-PBL students (Schmidt et al., 1987; Albanese & Mitchell, 1993; Vernon & Blake, 1993; Verhoeven et al., 1998). As small-group learning such as PBL has become a more prominent pedagogy (Collins et al., 1994), this trend may speak to the deficits in clinical anatomy application.

The literature slightly favored dissection's use in learning anatomy (Winkelman, 2007), however, the studies were limited, and few articles evaluated a single variable comparison. The use of a multimodal approach (CAL + dissection) outperformed either individual option (Biasutto et al., 2006). More recently, a study showed the use of cadaveric dissection led to far greater outcomes of anatomical knowledge compared to a group with the same resources and contact hours with instructors, but with no cadaver access (Anyanwu & Ugochukwu, 2010). The authors made the assertion that anatomy education suffered from an over-reliance on resources that were never meant to be more than supplementary. As an example, the authors cite that the early indications of the superiority of prosection over dissection (Nnodim, 1990) disappeared at the follow-up (Nnodim et al., 1996). Despite the long-term null finding, the academic community continues to cite the original findings to support curricular decisions of removing dissection.

CHANGING THE CONVERSATION

Despite numerous articles evaluating different teaching methodologies and potential mediators of learning, the literature is far from in consensus regarding the causes of the substandard clinical anatomy possessed by medical students and junior physicians (Bergman et al., 2011). Some opine that an inadequate causal determination is due to a lack of high-quality studies assessing how pedagogies and curricula impact anatomical knowledge (Bergman et al., 2013). The present review contends that this approach is inappropriate for answering the question; as it derives from the flawed assumption that anatomy is limited to a body of knowledge. The assumption is understandable. Diminished time and trained anatomists (Collins et al., 1994) produced a prioritization on assessing factual knowledge - driving students to memorization over reasoning (Miller et al., 2002). It does not take long for educators to conclude that anatomy no longer satisfies the nature of science (McLachlan & Patten, 2006; Pickstone, 2001); a decision visible across academia, scientific publications, and achievements in medicine (Dyer & Thorndike, 2000; Gawande, 2012; Toledo-Pereyra, 2006; Schlich, 2007). Ultimately, the implicit international narrative is that the anatomy course is not a place for science.

The anatomy education literature may reinforce this perspective more than any other source. In large studies on student and anatomist beliefs regarding best teaching tools, ratings are couched within 12 general anatomy objectives; none of which relate to scientific methods, habits of mind, or reasoning. (Kerbey, Shukur, & Shalhoub, 2011; Patel & Moxham, 2006, 2008). This trend also appears in interventional studies on common learning tools such as digital media (Tam et al., 2009), 3D physical models (Chan & Cheng, 2011; Yammine & Violato, 2015; Azer & Azer, 2016), and clinical correlations (Lufler et al., 2010; Phillips et al., 2013; Boon et al., 2002; Drake, 2007; Wood et al., 2010; Rosenson, 2004). Prominent reviews on best practices and effective teaching in anatomy education (de Jonge et al., 2008; Losco et al., 2017; Estai & Blunt, 2016; Bergrman et al., 2011, 2013) use measures of knowledge acquisition and retention in their inclusion criteria, determinations of effective interventions, and their suggestions for future research. Of note, only two intervention studies included in the present review measured clinically-relevant knowledge (Sarkis et al., 2014) or its application (Shiozawa et al., 2014) as a component of their study; neither appearing in any review of anatomy education.

The literature's inability to answer questions regarding best practices and contributors to insufficient clinical anatomy proficiency derives from its assumption that students only need anatomical knowledge for their present level of use (McLachlan & Regan de Bere, 2004; McLachlan et al., 2004; Collins, 2008). The error is restricting student-needs to a body of knowledge and neglecting the need for a system of processes that foster the reasoning-based applications of professionals. In essence, modern anatomy education is akin to vocabulary without grammar; variables without equations. A need exists to transition the conversation from asking "what is the best mode of learning vocabulary?" towards asking "how can we foster literacy for fluency?" From this framework, courses will best serve their students by engaging in anatomy the way it is used: as a science.

THE PHYSICIAN-SCIENTIST

Standards set by the Liaison Committee on Medical Education (LCME, 2016) and the Association of American Medical Colleges (AAMC, 2009), the accrediting and governing bodies for US medical schools, the training of future clinicians should emphasize more than acquiring a body of knowledge. Medical education should develop the processes that physicians will use in patient-care, or as Jolly & McDonald (1989) assert, education should be for practice. Among the LCME and AAMC guidelines are the development of medical problem-solving though critical thinking, appraisal of evidence, the formation of hypotheses that guide subsequent data collection, and the coherent, logical communication of a position. Healthcare practitioners combine these cognitive skills to conduct successful clinical reasoning: the process of diagnosing a patient's problem; forming the foundation for appropriate treatment options (Harjai & Tiwari, 2009; Brush et al., 2017).

Clinical reasoning, or clinical problem-solving (Alpern, 2011) is the fitting together of simple, discrete puzzle pieces that, when assembled correctly, reveal a picture of the truth. Success is often measured as diagnostic accuracy, which relies on knowledge, level of training, exposure to clinical presentation, and integration of accurate logic (Anderson, 1997; Mandin et al., 1997; Coderre et al., 2003; Vink et al., 2015). The early phase of gaining expertise as a diagnostician is through reasoning from causal networks (Schmidt & Boshuizen, 1993). This reasoning is formed through parallel processes of increasing biomedical knowledge and developing meaningful linkages amongst anatomy, physiology, mechanisms of disease, and symptoms. With experience and exposure to normative disease exemplars, these causal networks become encapsulated into intuitive constructs such as *hypertension* (Schmidt & Rikers, 2007). Physicians and students use these causal networks to engage in a *hypothetico-deductive* process wherein symptoms lead to the generation of potential hypotheses that can be differentiated through subsequent data collection and tests to determine the diagnosis (Campbell, 1987).

Many authors agree that the key to translating anatomy knowledge into practice requires a paradigm shift to better represent how students will use anatomy as professionals. A joint article written by education leaders within the American Physiological Society and the American Association of Anatomists identified that students engage anatomy through surface-level learning (Pandey & Zimizat, 2007) because that is how anatomy is taught and assessed (Miller et al., 2002). The article asserts that the process of learning to apply knowledge is as important as the knowledge itself, and that understanding for explanation and making connections provides greater educational value than memorization (Miller et al., 2002; Pandey & Zimizat, 2007) Additional support comes from parallels between the clinician's and the anatomy student's habits of mind, or "rhythms" (Rizzolo & Stewart, 2006). The physician answers questions by employing observation and history-taking to collect data, analyzing the data to generate and test differential diagnoses, and makes determinations of disease and intervention; a process mirrored in the dissection lab when answering questions regarding the identification of a structure: observation, interpretation, exploration, argumentation, and determination.

A study asking the question, "are medical students being taught anatomy in a way that best prepares them to be a physician?" used senior physicians and anatomists to develop a set of assessments representing the clinical and structural anatomy within the cardiothoracic specialty (Savran et al., 2015). The results showed that the anatomists had superior knowledge of factual and clinical applications compared to the participating physicians and students. When comparing the students who recently finished the course to the senior physicians, the students scored significantly lower on clinical questions but higher on factual questions. The authors concluded that, while the anatomy educators possessed ample clinical knowledge and reasoning, the course was not being taught in a way that adequately fostered these for the students. As Anderson (1997) states, integration of form and function must happen in the mind of the student for that knowledge to translate to reasoning and practice.

The role of anatomy education in healthcare training

Senior physicians extol anatomy in medical education, and while perceived importance of topics within the course varies by specialty, medical imaging consistently receives high ratings (Orsbon, Kaiser, & Ross, 2014). Junior physicians emphasize anatomy's role in acquiring clinical knowledge, connecting knowledge to practice, and interpreting diagnostic images (Sbayeh et al., 2016). Medical students agree with their professional counterparts regarding the fundamental importance of anatomy in clinical practice. In a survey by Moxham and Plaisant (2007) students strongly agreed with prompts such as,

1) It is impossible to conceive of good medical training without a major anatomy component,
2) It is not possible to make a reasonable medical diagnosis without anatomy, and
3) Of the basic sciences, anatomy is the most relevant

In fact, the students never reported agreeing with any prompt deemed "negative" towards the relevance of anatomy in clinical practice. A similar survey of medical students by Bockers and colleagues (2010) reported that the cadaver-based gross anatomy course enhanced acquisition of anatomy knowledge, and also facilitated development of competencies related to teamwork, stress coping strategies, and empathy. The students rated the dissection course as the most valuable subject in the preclinical curriculum.

A seminal piece on the value of anatomy in medical education is Older's 2004 review, which called the diminished emphasis of classical anatomy a choice made without evidence; choosing research funding over long-term patient welfare. Older indicates that the gross anatomy lab provides students the opportunity to

1) have an early encounter with mortality,
2) improve manual dexterity,
3) develop bonding and teamwork,
4) have direct experience with active learning,

5) verify facts from the primary source,
6) enjoy the art of discovery,
7) check the interpretation of others,
8) gain a three-dimensional understanding of the body, its variation, and pathology.
9) acquire communication skills.

According to Older, the gross anatomy lab is "a must for teaching the next generation," and will give students confidence and enrich their clinical competence. An open-response survey asking professional anatomists, "Why teach anatomy?" showed many of the respondents agreed with Older's (2004) assertions regarding anatomy's value (Paalman, 2000). While professional anatomists were amenable to modernization and improvement, there was a growing frustration with diminishing time, integration with other courses, and replacing dissection with problem-based (PBL) or computer-assisted learning (CAL).

The role of basic sciences in healthcare training

Recent work on the relationship between biomedical sciences and clinical reasoning has focused on diagnostic errors as these are the second leading cause of adverse events in patient-care as well as the second leading cause of malpractice lawsuits against hospitals (Leape, Brennan, Laird, et al., 1991; Bartlett, 1998). Woods, and colleagues (2005) posit that the value of the basic sciences derives from the training to develop causal explanations connecting signs and symptoms to diseases, which may provide a meaningful mental framework that aids in retention and application. As such, these connections would be superior to the more traditional use of probability matrices to aid in diagnoses. To test this assertion, the authors conducted an experiment to compare students' diagnostic performance using probability matrices vs. a basic science approach. The results showed similar performances on the immediate post-test (54% vs. 52%). However, on the delayed post-test, the probability group declined from 54% to 43%, while the general sciences group suffered no detriments in performance from the original 52%. To explain this bifurcation, the authors analyzed the immediate and delayed supplementary tests, which measured participant memory and understanding of probability data or relevant sciences. The results showed that the performance declined significantly in the probability group (42 to 25%), but not so in the general sciences group (74 to 64%). The authors concluded that the value of the basic sciences comes from the opportunity for students to develop a more robust mental framework that supports retention and retrieval for application.

To better understand the role biomedical sciences play in clinical reasoning, a study asked expert clinicians to verbalize their efforts to solve clinical cases. The physicians rarely mentioned fundamental biomedical principles. Rather, they focused on the analysis and interpretation of clinical features and only explicitly relied on biomedical principles when encountering a novel or challenging diagnostic problem (Joseph and Patel, 1990). As novice practitioners rely more on the causal networks provided by biomedical sciences (Vink et al., 2015), the results suggest that the expert clinician had encapsulated the biomedical knowledge within the context of the familiar disease pathway allowing for faster processing without explicit recall (Woods, 2007). In addition, biomedical knowledge also enhances diagnostic accuracy under difficult circumstances (Woods, Brooks, & Norman, 2007). As the biomedical sciences provide students with robust mental frameworks for retaining and applying information valuable in the clinical reasoning process, especially under challenging conditions, it may behoove curriculum designers to ensure that clinical reasoning integrates with the scaffolding that the biomedical sciences provide.

Summary

The juxtaposition of anatomy education with the methods used by the clinician demonstrate that anatomy courses are not fully-engaged in the preparation of students for careers in healthcare. Common terms used in anatomy are *identify, describe, appreciate,* and *list*. These are low-complexity demands (Bloom, 1956) only made challenging by a large volume of material covered too quickly. Rarely do questions of reason permeate conversations, and inquiries of, “why do you think that?” or “when might that (not) be true?” or “how can we determine that?” arise most-often during a disagreement over a particularly difficult structure. Even rarer in the anatomy lab are words such as *defend, apply, solve, evaluate, refute, predict, or develop.* As the common classroom strategies fail to use anatomy as a medium to engage students in the processes of scientific reasoning, it is necessary to explore pedagogical strategies intentionally designed to promote these cognitive skills through the exploration of laboratory content. One such model of laboratory learning is Argument-Driven Inquiry

A DIFFERENT APPROACH TO ANATOMY EDUCATION

Argument-Driven Inquiry in Laboratory Learning

Argument-Driven Inquiry (ADI) is a guiding model for science laboratory instructional design developed in response to guidance from the National Research Council on science education in the U.S. The 2005 NRC report on high school science education suggested that laboratories should (1) be more inquiry-based, (2) increase opportunities to read, write, and engage in critical discussions, (3) promote the construction or critiquing of arguments, and (4) include diagnostic, formative, or educative assessment throughout the activities. (NRC, 2005). ADI is a flexible 8-stage model that gives students the chance to develop their individual investigations, collect and analyze data, communicate ideas with others in structured, interactive argumentation sessions, write investigation reports, and participate in peer review processes (Sampson, Grooms, & Walker, 2009).

The stages of ADI are:

1. **The identification of a task/question** that creates a need for students to make sense of a phenomenon or solve a problem;
2. **The generation and analysis of data** by small groups of students using a method of their own design;
3. **The production of a tentative argument** by each group that articulates and justifies an explanation in a medium that can be shared with others;
4. **An argumentation session** in which each group shares its argument and other groups provide critiques;
5. **An explicit and reflective discussion** about the inquiry.
6. **An investigation report** written by individual students that explains the goal of the work and the method used, and provides a well-reasoned argument;
7. **A double-blind peer review** of these reports to ensure quality and generate high-quality feedback for the individual authors;
8. **The subsequent revision** of the report based on the results of the peer review;

The fundamental principle underlying ADI is that students and the instructor engage in a social constructivist approach to asking and answering questions in science. In social constructivism, knowledge and meaning are built within the mind of the individual; developing as a result of social interaction (Vygotsky, 1979; Palinscar, 1998). This is differentiated from *Social Learning Theory* which states that learning comes through observation rather than interaction (Bandura, 1973). The environment of ADI laboratories fosters communication and collaboration among the participants. These interactions allow knowledge, ideas, and understanding to be absorbed, shared, critiqued, and refined; forming a natural framework for formal argumentation. Argumentation in this context does not carry the emotive negative connotations that it may in general conversation. It is simply that: a conversation (NRC, 2007). Kuhn (1991) states that argumentation in scientific domains is less confrontational than in other formal arenas such as debates. Argumentation can also be defined as an explanation supported by one or more reasons (Sampson, Grooms, & Walker, 2009). The NRC's 2007 report on science education defines argumentation as "a mode of logical discourse" intended to parse out connections between an idea and the present evidence (NRC, 2007). Argumentation plays a pivotal role in the practices of reasoning, capturing ideas, and expressing and evaluating explanations and evidence. Because of this, the National Science Education Standards (NSES) use it as a defining component of inquiry such that inquiry is not just a process of "exploration and experimentation," but also a process of "explanation and argumentation" (NRC, 1996). Studies on ADI in the classroom have emphasized a shift from procedural, prescriptive laboratory instruction to the use of developing scientific literacy to engage course concepts.

In 2010, Sampson, Grooms, and Walker explored the use of ADI in a 10th-grade chemistry course. Results showed that ADI can improve the scientific argumentation as it relates to disciplinary engagement (e.g., cognitive and social norms). The authors noted that the students tended not to use theoretical models or laws to explain phenomena or in the appraisal of ideas. Two proposed reasons for this were: (1) a lack of knowledge/understanding of the theories and models, and (2) an insufficient encouragement for their use.

In an extension of this work, Sampson and Walker (2012) applied ADI in an undergraduate chemistry course to explore the changes in students' ability to write with to a scientific standard over 15 weeks of instruction. The authors found that the student-generated reports improved significantly over the study and that the peer-reviews attained a relatively-high level of accuracy. However, most students did not reach the level of proficiency defined by the authors and the authors posited this may have resulted from the limits of what can be achieved in a single, course of study. Despite this, ADI does appear to be a more efficient method of instruction. Walker et al. (2012) found similar levels of conceptual understanding following a 15-week chemistry course between participants in ADI labs and standard labs despite the ADI group participating in fewer lab sessions. The ADI students also showed improvement in argumentation in familiar and unfamiliar contexts. Additionally, female participants in the ADI group reported a significantly higher attitude towards science compared to females in the traditional labs; a potential piece of evidence for ADI's framework to support engaging women in science.

In a follow-up study, Walker and Sampson (2013) reported improvements in written and oral argument quality with ADI labs in an undergraduate chemistry course along a positive correlation between the quality levels of the collaborative group argument and the individual member argument. This suggests that the collaborative nature of ADI may support the further development of scientific skills across the group. In Grooms, Enderle, & Sampson (2015), a comparison of 2 high-school chemistry courses (ADI vs. Non-ADI) showed effect size gains (Cohen's *d*) pre- to post-course for the ADI group in content knowledge (d = 1.94), scientific writing (d = 0.25), and performance task (d = 0.6). The only gain the non-ADI group experienced was in content knowledge (d = 1.24). These results clearly indicate the difference between the potential of ADI vs traditional instruction.

The parallels to the teaching of anatomy are clear. As with problems in anatomy education (Miller et al., 2002; Savran et al., 2015), the content knowledge of the traditional labs did not translate into student abilities to “analyze data, critique a flawed argument, and provide an alternative argument” (scientific writing). Nor, did it translate to student abilities to “develop and conduct and investigation to identify an unknown and provide and argument in response to a guiding question” (performance task) (Grooms, Enderle, & Sampson, 2015). The crux of the problem with traditional science laboratories comes down to the reason for reasoning. Reasoning matters because it is the skill that enables the individual to use knowledge to understand, describe, explain, evaluate, and design. It is the equation logic that facilitates the computations of discrete variables. The proficient use of reasoning is essential to learning, knowing, and growing in any personal or professional environment (Cutrer et al., 2017). Ultimately, reasoning is the skill that allows the student to transition from answering the instructor’s questions to begin generating and answering their own. In a social constructivist framework, ADI’s emphasis on collaborative, authentic scientific practices and cognitions through argumentation provides a theoretically-sound and data-driven template for engaging reasoning in the anatomy laboratory (Manyama et al., 2016). Additionally, ADI continues to model well across domains of physical and biological sciences (Grooms et al., 2016; Enderle et al., 2012; Sampson et al., 2013; Walker & Sampson, 2013).

Cadaver-Based Medical Procedures. Doing what Physicians Do.

When reviewing ADI, it becomes apparent that there is a fundamental understanding that *learning* science requires *doing* science. The cadaver dissection lab mimics the rhythms of the clinician (Rizzolo & Stewart, 2006), yet, there are opportunities to better engage anatomy in a clinically authentic manner using medical procedures. When students perform genuine medical practices, they have the opportunity to (1) change the way they think about fundamental knowledge and principles, (2) link theory to practice, and (3) engage in the clinical reasoning that uses the relevant anatomy to understand, explain, evaluate, and develop interventions for multiple disease states (Jolly & McDonald, 1989; Kovacs,1997).

There is a notable difference in the present review's operationalizations of *procedure-learning* and *clinically-correlated learning* (previously mentioned). The former aims to develop confidence and competence in understanding and performing a genuine medical procedure. The latter aims to allow the student to view the relevant anatomy within its clinical context, as if to see it the way the physician does. Therein lies the difference: *seeing* what a clinician sees vs. *thinking* how a clinician thinks. In *clinically-correlated learning*, the procedure is another method of visualization, but *procedure-learning* promotes the real cognitions of the physician:

> "Why am I doing this?"
> "Is this the correct method or procedure for this situation?"
> "Am I at risk of damaging the underlying anatomy? How can I tell?"
> "How does the procedure rely on the anatomy?"
> "How does variation in the underlying anatomy change my approach?"

Among the potential benefits of *procedure-learning* over diagnostic reasoning is that the answers to these questions require more learner-directed inquiry. In a diagnostic reasoning activity, a device that can access online resources such as Google and Up to Date can quickly allow a student to circumvent developing reasoning-based skills. However, in a dissection lab, the nature of the environment is less conducive to this path of least resistance. Additionally, the wide-range of conditions indicated by a single procedure can make it nearly impossible to conclude a “right” answer. *Procedure-learning* additionally puts students in the mind of the practitioner by putting the tools of the practitioner in hands of the student. Learning to understand and manipulate real medical technology provides for a more authentic experience and generates opportunities for developing true habits of mind. Thus, the use of *procedure-learning* provides a rich environment to do what physicians do.

While the majority of literature exploring cadaver-based procedural learning focuses on junior and senior physicians, there is some evidence to support its use in medical school settings. For students in the clinical years (post-science coursework), learning with cadaver-based procedures shows up as early as 1986 (Weaver et al., 1986). The research in this area is consistently positive for building procedural confidence/comfort and proficiency (Weaver et al., 1986; Morton et al., 2006; Chandler et al., 2016; De Win et al., 2016), understanding of the clinical procedure (Kaplan et al., 2013), and validating approaches to teaching cadaver-based procedures to medical students (Kay et al., 2016). In light of these positive findings, the lack of literature on *procedure-learning* for pre-clinical students continues to demonstrate the motif that there is not time for anything other than the content.

Summary

To-date, anatomy education is failing to meet the needs of its learners. Researchers continue to work under the flawed assumption that anatomy has become the Latin of modern science; a dead language limited to providing a framework and source of common vocabulary.

Anatomy is rarely engaged in its clinical form in basic science classrooms and even rarer is it assessed through reasoning. Argument-Driven Inquiry provides a potential pedagogical template for facilitating the development of the cognitive skills necessary for any healthcare practitioner. Additionally, the use of *procedure-learning* in cadaver labs may build upon the ADI precepts with greater fidelity than a standard dissection lab. However, these approaches to learning anatomy represent a substantial bifurcation from modern perspectives. As such, they are largely absent in the literature. Therefore, a need exists for foundational research to better understand and inform efforts towards fully implementing ADI in the anatomy laboratory. Once initial procedures have been developed and supported more formal efficacy trials can be completed to test their impact on student learning.

Given the different levels of anatomic instruction, the foundational research should mimic those levels. Specifically, the approach to ADI differs when applied in a medical school setting - with access to cadavers and physician instructors - from the undergraduate setting that in many cases uses video or models to illustrate the human form. This leads to qualitative differences in the application of ADI in the undergraduate and medical school settings. To this end, this dissertation developed ADI-based approaches at both the undergraduate (Study I and 2) and medical school (Study III) levels. Neither of these was designed as a test of ADI. They were, instead, designed to provide the foundational research required to support future efforts to apply and test ADI as an approach to anatomical instruction.

CHAPTER III: RESEARCH STUDIES

STUDY I

Methods

Design

The first study piloted the implementation of a limited version of the argument-driven model in one undergraduate human anatomy laboratory section as a proof-of-concept that ADI could be implemented in anatomy without a detriment to students' academic performance. A detriment to student performance was defined as substantially lower scores on the post-lab quiz and/or the lab exam for the pilot group compared to the non-pilot labs. If the procedure demonstrated a significantly negative impact on student academic performance, the methodology would have required restructuring prior to progressing to Study II. As students enrolled in lab sections independently, this was a quasi-experimental design conducted as a non-randomized control trial.

Standard Lab Procedures – Control

Before a description of procedures, it is important to understand the context of the undergraduate laboratory sessions. Approximately 18-25 students attended each 2-hour lab session held in the afternoon or evening. Each lab section was facilitated by a single instructor, and was supervised by the lab director. The lab instructors facilitate up to three sessions per week, and are responsible for the general flow and management of the session. The lab is designed to be student-driven, and the instructors are available for guidance, clarifications, and grade inquiries.

Prior to attending each lab session, the students completed assigned pre-reading and worksheets from their lab manual, online videos, as well as an associated online multiple-choice quiz. During the lab session, the lab instructor spends 10-15 minutes on announcements and reviewing the post-lab quiz from the previous week's lab session. Following the instructor's review, the students have the remaining 85-90 minutes to work together in groups of 3-5 to complete a lab worksheet. The worksheet requires them to answer questions identifying and describing labeled models and PowerPoint histology slides. The lab instructor was available to answer questions and may conduct a short introduction to the session's content. While students are working in their lab groups, the instructor briefly checks to see that they have completed the pre-lab worksheets in the lab manual. At the end of the session, students must check with the instructor and show their completed worksheets. Students have a 24-hour window to complete an online post-lab quiz following the conclusion of the lab session.

Pilot Argument-Driven Laboratory Procedures – Intervention

Prior to attending the lab session, the students completed the same pre-reading, worksheets and the online quiz as the standard lab groups. They also reviewed the previous session's post-lab quiz, the "spot-check" of pre-lab materials, and the online post-lab quiz as in the standard lab. During the 2-hour lab, students worked in groups to complete two rounds of a limited version of the Argument-Driven Inquiry model (Stages 1-4). The first round focuses on the musculoskeletal components of the elbow, and the second focuses on the distal forearm and wrist.

STAGE 1. *The instructor identifies a guiding question or task.*

The instructor informed the students that there are a series of patient x-ray films that show injuries. The students is asked to ultimately predict the functional outcomes expected for the patient.

STAGE 2. *A laboratory-based experience where small groups of students have an opportunity to* ***generate or analyze data*** *using appropriate tools.*

The students utilized provided materials to evaluate sets of open-source patient x-ray radiographs for fracture sites. Students received normal x-rays with labels, diagrams, and 3-D models to facilitate familiarization, orientation, and to identify fracture sites on the patient x-ray scans.

STAGE 3. *The production of a* ***tentative argument*** *that articulates and justifies an explanation on a medium that can be seen by others*.

Using a structured word document (patient analysis form), each group constructed an argument that (1) identifies the skeletal injuries sustained by a "patient" from X-ray scans, (2) using anatomical terminology, provides a locus of pain, (3) proposes impacts to surrounding connective tissue and musculature, and (4) predict impacts to functional movements. The students then synthesize the claims and evidence into a cohesive written paragraph for submission. The students used the relevant structures found in their lab manual to guide their discussion.

STAGE 4. *An* ***argumentation session*** *where groups share their arguments and then critique and refine their explanations*.

As the laboratory section has a limited amount of time and groups naturally finish their patient tentative arguments in varying order and at different times, the lab instructor engaged with each group in the argumentation session. The groups presented their written summary argument and the instructor asked questions afterwards. The students had an opportunity to correct, clarify, and refine their terminology and logic. The instructor also guide the students regarding time-constraints, answer questions, and engage in a constructive questioning and critique of each group's argument. The instructor did not provide a didactic lecture.

These ADI stages (1-4) were selected for this pilot as they are the primary in-class components of the model. As the anatomy laboratories often provide the most efficacious opportunities for learning content, these stages represent a significant logistical challenge to student performance. Ineffective implementation in the lab had the potential to negatively impact student outcomes. As such, the focus of this pilot was to determine if student performance was maintained. If so, this was considered sufficient to consider additional investigation. Additionally, these stages provided the most opportunities for variability. Therefore, it was necessary to identify potential sources of variability, address student concerns, and observe the actual processes students used to engage the content within a scientific-reasoning framework. This, provided the basis for further testing in the undergraduate population for Study II.

Setting

This study occurred in one laboratory section in the undergraduate Applied Human Anatomy Course. This is a non-cadaveric dissection lab.

Participants

Study I utilized the students enrolled in of the Applied Human Anatomy course. While all students participated in the lesson, only those who provide informed consent provided data for this study. As a result, exclusion from participation only apply to the data of non-consented students and did not restrict their involvement in the laboratory section. Data from students previously enrolled in the course was excluded. No compensation was provided for participation. In the event that the pilot resulted in a detriment to student academic outcomes, the course director agreed to apply a grade curve to the exam for the pilot laboratory section.

Materials

This study leveraged existing technology and learning materials within the lab. The lab was equipped with 47-inch flat screen TV monitors at each lab station. These monitors were able mirror each group's computer screen. This allowed students to work collaboratively within their groups. The students received access through the online course management system (Canvas) for:

1. "Clinicals Directions" for the conducting the patient analyses (appendix)
2. electronic versions of open access patient x-ray radiographs (www.radiopaedia.org),
3. labeled normal x-ray scans,
4. relevant (non-radiograph) labeled diagrams, and
5. a structured "Patient Analysis" word document to guide their data collection and analyses (appendix).

These materials are specific to the musculoskeletal components of the elbow, forearm, wrist, and hand. The students also had access to 3-D models of all relevant musculoskeletal structures including:

1. Plastic bone models
2. Plastic articulated limbs

3. Articulated skeletons
4. Plastic limb muscle models
5. Plastic joint models with ligaments
6. Plastic joint models with muscles

Each group had the 3-D models at their respective tables and a TV monitor on which to work.

Outcomes & Measures

Study I used the score of the subsequent lab exam (appendix) to measure knowledge-level learning outcomes and to assess how they were impacted differentially between the two lab procedures (pilot ADI vs. standard practices). The lab exam was comprised of approximately 90 items targeting students' ability to identify structures and describe their functions. The prompts are in level 1 (knowledge) or level 2 (comprehension) of Bloom's taxonomy (i.e., low demand complexity). There were an additional 5 clinical application questions ranging in complexity, and asking students to list, describe, or explain the relevant anatomy within a clinical scenario. The exam was paper-based, and combined fill-in-the-blank, short-answer, multiple choice, and true/false. Students had 120 minutes to complete the exam. The lab exam was split into 4 sections:

(1) 3D model practical – 20 models (50%)

(2) PowerPoint slide histology slide practical – 10 slides, (30%)

(3) Multiple choice questions – 10 questions, (10%).

(4) Free response questions – 5 questions, (10%)

The students began the exam in the 3D model practical stage, but were able to answer questions from other sections at any time. The histology PowerPoint slides were set to rotate on a 30-second timer.

Example questions:

Model

A. What is the proper anatomical name for this joint? ___________________________

B. Structurally, what kind of joint is it (be specific – 2 terms)? _________________________

C. This joint allows for movement in ____ planes so it is ___________________________.

Slide

This is a tissue section from the small intestine.

1. What kind of epithelium is the arrow pointing to? ___________________________
2. What would be a possible function for this epithelial layer? ___________________________

MCQ:

This superficial muscle covers a large part of the posterior thorax.

A) trapezius
B) rectus abdominis
C) rhomboids
D) pectoralis major

Clinical Application:

Over time, smokers develop a persistent cough known as 'smokers cough.' Cigarettes cause damage to the epithelial lining of the respiratory tract. What epithelium lines the upper respiratory tract, what specific structures are damaged by the cigarettes, and why does this lead to a cough?

The factual knowledge items were scored by the course instructors according to an exam key developed collaboratively by the instructors. Each instructor was responsible for scoring a specific set of items to ensure consistency. Exam scores were reviewed collectively to ensure the scoring represented the preferred practices of the group. As factual anatomy items carry little variability, the variety of scorers presented little opportunity for bias.

Data Analysis

Study I conducted a two level (pilot vs standard), One Way Repeated Measures ANOVA to compare exam means between the 7 laboratory sections. The null-hypothesis is that there was no significant difference between the pilot lab and the standard practices lab.

Timeline

The intervention took place during the 5th week in one lab section. The six lab sections that do not receive the intervention acted as the control; carrying out the standard worksheet-based laboratories. The subsequent lab exam (practical 2) examined differences in factual knowledge achievement two weeks after the intervention lab.

Resources & Funding

This study did not require funding, and leveraged existing material resources in the laboratory space.

Consent Process

The course directors permitted the study to be implemented as a quality improvement project, meaning that all of the students in the course completed the laboratory assessments and lab sessions as part of the course. The students were recruited to participate in a departmental study to evaluate the use of ADI in the Applied Human Anatomy lab. They were asked to sign a written informed consent document permitting their academic data to be used for analysis.

Limitations

This pilot was limited to exploring the impact of the in-class components of the ADI model and did not include all components of ADI. Therefore, the results of this study did speak to the true effect of implementing ADI in the anatomy laboratory. However, as ADI had not been implemented previously in an undergraduate anatomy course, the results and logistical information gathered informed future testing. Additionally, as this is a 1-week pilot intervention, the study is unable to analyze the development of argumentation as an outcome.

Assessment of learning outcomes in the undergraduate lab was measured with delay to coincide with the laboratory exam schedule required by the larger course. This delay may have diminished group differences as the students had opportunities to independently enhance their learning in preparation for the exam. The learning outcomes for the undergraduate students were not measured in an immediate pre-post methodology due to the larger course using existing pre-post quizzes. These quizzes were not incorporated for two reasons. First, they were accessible online and had the potential for confounding factors such as using the textbook or an internet search to answer. Second, the questions were solely lower level cognitive tasks that did not demonstrate sufficient variability to provide a fair assessment.

While these limitations exist, they were natural challenges to pedagogical research without the full control available to the course instructor. However, the primary purpose of this project was to act as a proof-of-concept that the most disruptive format of ADI would not impair academic outcomes for students. As such, this pilot focused on identifying potential threats to internal validity and effective implementation of ADI.

Results

The Intervention Lab

A 3 x 1 ANOVA tested for mean differences on the lab exam following the intervention lab. No interactions were present. Only the main effect of Sex was significant $F(1, 89) = 5.43$, $p = .02$, $d = .4$, demonstrating male students scored approximately 8 points higher on the exam than female students. The intervention lab exam score was not significantly different ($p > .05$) from any of the other 6 control lab sections; including the other two lab sections taught by the PI.

Instructor Differences

There was not a significant difference in scores on the exam following the intervention based on the instructors ($p = .91$). The largest mean difference between instructors was 3.46 points ($SD = 15.9$) (see Table 3.1).

Lab Exams

The analyses for Study I included data from 103 undergraduate anatomy students after excluding 13 participants' data for being incomplete or an outlier. Descriptive statistics can be found in Table 3.1. A RM-ANOVA was conducted to test for mean score differences across the 3 Lab Practical assessments. There were no interaction effects, and the significant main effects were Lab Practicals $F(2, 89) = 30.07$, $p < .001$, and Sex $F(1, 89) = 6.33$, $p = .014$, and explained 25% and 7% of the variance, respectively. The main effect of Lab approached significance at $p = .09$. Pairwise comparisons with the Sidak adjustment for multiple comparisons showed that the mean score for Practical 3 ($M = 76.96$) was significantly higher ($p < .001$) than Practicals 1 ($M = 68.52$) and 2 ($M = 71.39$). The mean score for Practical 2 was significantly higher than Practical 1 ($p = .04$). Pairwise comparisons with the Sidak adjustment showed that, on average, male students scored significantly higher ($p = .041$) on practical exams than female students (mean difference = 6.23). A one-way ANOVA was conducted to test for this difference on each Lab

Practical according to Sex. The results indicated that male and female students did not differ significantly on the first Lab Practical $F(1, 102) = 2.44$, $p = .12$. However, Practicals 2 and 3 showed significant mean differences wherein males scored higher than females. The Practical 2 mean difference was 7.63 ($p = .02$), and the Practical 3 mean difference was 8.11 ($p = .01$). Sex accounted for 2.4% of the variance for Practical 1, 5.3% of the variance for Practical 2, and 6.3% of the variance for Practical 3. While the effect of Sex is significant for Practical 2, the effect size magnitude is small. However, Sex had a moderate effect size on the Practical 3 scores.

Lecture Exam Performance

A repeated measures ANOVA was conducted to test for differences in mean performance across the four lecture exams. There were no interaction effects, and only the main effect of Exam was significant $F(3, 87) = 27.08$, $p < .001$; explaining 26% of the variance . However, the Lab and Sex factors approached significance at $F(3, 87) = 2.44$, $p = .07$, and $F(1, 87) = 3.476$, $p = .07$ respectively. Pairwise comparisons between lecture exams using the Sidak adjustment for multiple comparisons showed that the mean performance on Exam 2 ($M = 89.66$) was significantly higher than all other exams ($p < .001$). The mean scores for Exam 1 ($M = 86.14$) and Exam 4 ($M = 84.65$) did not significantly differ ($p = .401$), but were significantly greater than Exam 3 ($M = 81.66$) ($p < .05$).

Discussion

The research question posed in this pilot study reflected a local curricular concern. The question pertained to the potential for an Argument-Driven Inquiry lab to be detrimental to the academic performance of students due to the unknown ability of ADI to be completed within the designated lab time. While the pilot intervention did not appear to hinder the ability of students to acquire the course content knowledge, it also did not fully represent an authentic implementation of the ADI methodology. The intervention was certainly clinically-oriented, collaborative, and argument-driven, but it lacked a large enough portion of the framework to be called "Argument-Driven Inquiry." This was the result of a curricular decision made by the laboratory instructor to prohibit the pilot from requiring additional out-of-class work, or decreasing the course content in any way. In order to comply with these constraints, the ADI model was pared down to the stages that could be successfully completed within the allotted time, as well as permitted the comprehensive coverage of the designated course content. Despite the restrictions, the incorporated stages sufficiently approximated the in-class ADI components to demonstrate that anatomy content could be adequately covered in an argument-driven manner. Future research is necessary to test whether ADI can be implemented fully to provide a more robust test of its efficacy in promoting student learning. Based on the experiences in Study I, it was clear that the full, traditional approach to ADI was not possible within the constraints of the course. Until such tests can be conducted, these data do not provide sufficient support for adopting ADI into the anatomy lab.

The results indicated that there was no significant difference in performance on either the lecture exams or lab practicals according to lab group. Specifically, Lab 7 acted as the intervention group, and any potential impact from the ADI lab activity would have presented on Practical 3, which was the subsequent assessment to the ADI session. However, the results indicated that the Lab group factor did not have a differential impact on the lab practical scores. These results indicated that the ADI lab session did not negatively impact the ability of students to answer low-demand questions.

The lab practicals showed an overall increase in scores over time, which is consistent with testing effects. The one independent variable that seemed to produce an effect on scores was Sex. While male students scored higher, overall, on the lab practicals, this effect only reached statistical significance on the second and third practicals; with small and medium effect sizes, respectively. This seemed to demonstrate a differential learning curve between the sexes, which may speak more to the nature of the course than to the impact of the ADI lab session. It is possible that the standard laboratory's lack of structured and intentional social construction of knowledge and meaning may be more detrimental to female students (Walker et al., 2012; Hakkikadayifci & Ayseyalcin-Celik, 2016).

Limitations

There are several potential limitations regarding the ability to observe an impact of a modified form of ADI on anatomy lab practical performance. First, there is no immediate post-test comparison between lab sections during the week of the ADI lab session. This challenge arose due to the course structure having a post-lab quiz system that would not facilitate a sufficiently-controlled assessment. Second, the implementation of a single ADI session in only one lab section for one lab session may be an insufficient dose to produce an effect. By multiplying the number of students in the course by the number of lab sessions, a potential "lab exposure" can be calculated (e.g., - 103 students x 10 lab sessions = 1030 lab exposures). In the present study, the ADI lab would amount to less than 2% of the lab exposures for the course. Third, the presence of a review week between the ADI lab and the assessment presents a potential wash-out of ADI effects. However, it is unlikely the dose and delay limitations are additive, and if ADI did present a threat to exam performance, then it is possible that the review week acted as a protective measure to allow the students in the ADI lab session to catch up. It should be noted that the content covered in the ADI session represented at least 25% of the points on Practical 3. With such a large proportion of designated points, it is unlikely that a substantial deficit caused by the intervention lab would not appear in the overall exam score. Additionally, the content covered for Practical 3 included the entire musculoskeletal system, the circulatory system (heart and blood vessels), and the nervous system (central and peripheral). It stands to reason that, with such varied and extensive materials on one assessment, one week of review would be insufficient to completely nullify a significant negative effect from ADI. However, a single week may be sufficient to allow students to catch up from a minor negative impact. Lastly, the nature of the assessments may not allow students to demonstrate any acquired reasoning skills. The assessment items focus on the ability to recall names, categories, and functions of anatomical structures. The absence of an identifiable effect on assessment performance may simply result from the assessment's inability to capture the reasoning-based skills ADI seeks to develop. This was be addressed in Study II to introduce an assessment to adequately capture reasoning-based application of the course content.

Future Research

While it may be reasonable to conclude that the intervention did not have a significant negative impact on student exam performance, there are potential ways to improve the study to better answer questions regarding the feasibility of incorporating ADI within the anatomy laboratory. First, the exposure of ADI can be increased in future studies by incorporating it within a greater number of lab sessions and lab sections, which can alleviate a number of limitations in the current study. It is unknown if there is a threshold dose for ADI exposure that stimulates reasoning skill development, and if instructors continue to express trepidation regarding a complete course overhaul, then an increase to four ADI lab sessions for all lab sections may be a reasonable compromise. While this increase to a 40% ADI exposure may not be sufficient to produce an effect, an incremental approach to implementing such a novel method of critical reasoning instruction may be preferable in a field that tends to emphasize the achievement of a high volume of lower-level factual knowledge. Additionally, the effects of engaging in four weeks of ADI methodology may not be washed out by the course's standing review week prior to the exam.

Future research can also increase the exposure of students to ADI in the lab by incorporating more of the ADI components such as writing an argument, engaging in peer review, and revising the argument according to the feedback received. Addressing the issue of the assessments' sensitivity to changes in critical reasoning skills may be accomplished by incorporating items that require students to engage in cognitions beyond rote recall of facts. Such items can be structured as clinical vignette prompts that require students to apply their anatomical knowledge to engage in problem solving or logical reasoning.

Finally, future studies should pay attention to the differential impact that the ADI methodology may have on female students. In this study, male students' performance outpaced their female counterparts. As female students comprised the majority of the course, it is crucial to consider how the structure may be disadvantageous for them. Considering these results along with research showing female students' scientific performance outcomes improved in an ADI chemistry course (Walker et al., 2012), the continued exploration of how ADI can be effectively implemented in the human anatomy laboratory will be valuable.

STUDY II

Methods

Design

The second study was an expanded, though still limited, implementation of ADI in the undergraduate anatomy laboratory covering the 4 weeks of musculoskeletal components related to the appendicular skeleton. To allow all students to be assigned to the intervention, the study occurred over two semesters. The first semester acted as the control (standard practices) and the second semester acted as the intervention. This allows all students in the second semester to be assigned to the same, 4 week exposure to ADI to teach the musculoskeletal components of anatomy. As the argument-driven lab sessions occurred after the midterm exam, this assessment acted as the pre-test. The final exam acted as the post-test. As the implementation occurs in sequential semesters, and students enroll in laboratory sections independently, this study employed a quasi-experimental design executed through a non-randomized control trial.

Modifications from the Pilot

The first major modification of Study II came as the result of a curricular change. The laboratory schedule historically covered the musculoskeletal components of the upper and lower limbs in two weeks. It was deemed that due to the course's location with a kinesiology department, and the fundamental role that the musculoskeletal system plays in movement sciences, it would be more appropriate to spread this content over 4 weeks. Additionally, the lab transitioned the exam schedule to fit a mid-term and final exam schedule. For Study II, the musculoskeletal content comprises the middle 4 weeks between the mid-term exam and the final exam. The other weeks are the cardiorespiratory system (immediately after the midterm) and a review week (immediately before the final). The addition of the cardiorespiratory system allowed for a comparison between content experienced with and without ADI.

The pilot experience also greatly informed the structure and modifications that exist in Study II. Among the lessons learned was the value of time. Some of the directions within the pilot study instructed students to use the "think-pair-share" technique to initiate individual contributions and to work more efficiently. In the end, it was an unnecessary step that hindered communication by forcing everyone to silently think (and wonder who would break the quiet first), and did not save time. The students were engaged in the activity from the start, finding it unique and stimulating. Additionally, there were concerns from the students regarding clarifying learning objectives and primary content. This led to the creation of the laboratory objectives, the muscle lists, and the structure/function lists (appendices). The content knowledge among the three was the same but were initiated differently. For example, the function of a bony landmark (structure lists) acts as the attachment point for a muscle whose function is to move a different bone (muscle list), which stabilizes a joint (objectives list). Students were instructed to complete these lists prior to attending lab. If they were unsure, had difficulty finding an answer, or believed that multiple or conflicting answers existed, the students were encouraged to bring those issues to the lab and discuss them with their groups and/or lab instructor. Doing so served two purposes: (1) help identify disconnects between course content expectations and student perceptions, and (2) provided a conversational starting point within and between lab groups to develop understanding and identify reasonable answers. Ultimately, these lists answered the question, “what do we need to know for the test?” and freed students to use that information to answer questions and solve problems. It should be noted that at the time of the first week of the ADI implementation (Lab 7), students did not have sufficient knowledge to complete this list. As a result, the list was not required. For labs 8-10, the lists were completed prior to lab in an effort to provide a richer argumentation conversation. Minor adjustments were made to the patient analysis form and to the assessment format. Namely, boxes were inserted into the documents. These boxes helped visually organize and separate students’ work on the patient analysis form and acted as a boundary for responses on the assessment that were too long.

In order to minimize confounding effects from the additional materials (objectives, structure/function list, and muscle list), the content was taken directly from the standard lab materials (appendices). The following samples from the Lab 9 materials illustrate how the ADI labs mirrored the content of the standard labs. It is important to note that the ADI lab lists and corresponding tasks (e.g., writing the action of a muscle, or the function of a bony landmark) were matched to the activities in the standard labs. While not every standard lab task appeared in the ADI labs, the ADI list tasks did not provide the intervention group with any form of additional content or cognitive process not present in the control group. The content and body regions in the four ADI labs matched completely with the content and body regions being studied in the standard lab counterparts.

A.1.) Standard lab muscle flashcard

Muscles Acting on Thigh and/or Leg (insert onto femur, tibia and/or fibula)
Anterior View (7):

- Iliacus
- Psoas major
- Sartorius
- Rectus femoris
- Vastus lateralis
- Vastus intermedius
- Vastus medius

A.2.) ADI lab muscle list

1. Anterior View

Muscle	Action
Iliacus	
Psoas Major	
Iliopsoas	
Sartorius	
Rectus Femoris	
Vastus Lateralis	
Vastus Intermedius	
Vastus Medius	

B.1.) Standard lab activity content

Ligaments of the Hip Joint (Model A) - Identify the following labeled structures on the model and answer the associated questions.
A. This is a posterior / anterior view of the hip joint.

So, this is a right / left hip joint.
B. Bony landmark: ___________________________
C. Bony landmark: ___________________________
D. Bony landmark: ___________________________
E. ___________________________
F. ___________________________ ligament
What 2 bones is it attached to? ___________________________

G. _________________________ ligament
What 2 bones is it attached to? _________________________
The two ligaments above are on the anterior / posterior side of the hip joint.

B.2.) ADI lab structure/function list:

6. CONNECTIVE TISSUES OF THE PELVIS

Structure	Function (if no clear function, provide a description)
Acetabular Labrum	
Ligamentum Teres (Ligament of the head of the femur)	
Joint Capsule	
Iliofemoral Ligament	
Ischiofemoral Ligament	
Pubofemoral Ligament	

C.1.) Example objectives from the standard lab materials

Objectives:
1. Identify the bones of the pelvic girdle and know its primary function.
2. Know the important bone markings on the ileum, ischium, pubis, sacrum, and the femur.
3. Know how to differentiate and explain the differences between a male and female pelvis.

C.2.) Example objectives from the ADI lab materials

1. Describe the structure of the **Pelvis**.
    a. List the 4 bones of the pelvis.
    b. Identify the 3 bones of the "Os Cox" or "Coxal bone."
    c. Describe the articulations of the 4 bones of the pelvis, and provide the anatomical name(s).
    d. Describe the anatomical differences between the male and female pelvis.

Another addition derived from Study I was the inclusion of a "helpful hints & keys to success" section within the directions (below).

1. Start with the question, "What am I looking at?"
2. Follow that with the question, "What does that do?"
3. Finish that series of questions with, "How does that fit into the function of the joint?"
4. When "EXPLAINING" anything, **provide evidence** (how you know) to show how you got to your answer.
5. Before you finish, always ask the questions:

I. Is this accurate? (Is everything I said true?)
II. Is this complete? (Did I include all the relevant information?)
III. Did I use all of the relevant anatomical terms?
IV. Did I support my claims with evidence?
V. Did I communicate clearly and succinctly?

This section was included explicitly to accomplish two goals: (1) Provide guidance and structure to the construction of arguments without actually saying "argumentation;" (2) Provide a clear pathway to "success" for the students. While avoiding the "argument" term is not ideal, it is the result of not having a sufficient control over the curriculum to teach the basis and purpose of argumentation.

Standard Lab Procedures: Control

Prior to attending the lab session, the students completed assigned pre-reading and worksheets from their lab manual, online videos, as well as an associated online multiple-choice quiz. During the lab session, the lab instructor spends 10-15 minutes on announcements and reviewing the post-lab quiz from the previous week's lab session. Following the instructor's review, the students have the remaining 85-90 minutes to work together in groups of 3-5 to complete a lab worksheet. The worksheet requires them to answer questions identifying and describing labeled models and PowerPoint histology slides. The lab instructor is available to answer questions, and may conduct a short introduction to the session's content. While students are working in their lab groups, the instructor briefly checks to see that they have completed the pre-lab worksheets in the lab manual. At the end of the session, students must check with the instructor and show their completed worksheets. Students had a 24-hour window to complete an online post-lab quiz following the conclusion of the lab session.

ADI Lab Sessions - Intervention

Prior to attending the lab session, the students completed the same pre-reading, worksheets, videos, and online quiz as the standard lab groups and review the previous session's post-lab quiz, the "spot-check" of pre-lab materials, and the online post-lab quiz. During the 2-hour lab, students worked in groups to complete two rounds of an adapted version of the Argument-Driven Inquiry model (Stages 1-4). To help clarify processes and expectation, the PI facilitated the first week of implementation to serve as a model for other lab instructors (Lab week 7). The PI began by modeling the students' process of working through the initial familiarization (representing the "Helpful Skills & Keys to Success"), which includes the integration of the patient x-rays, labeled references, diagrams, physical 3D models, and the living body to develop a mental framework from which the patient analyses can occur.

STAGE 1. *The instructor identifies a guiding question or task.*

The instructor informed the students that there are a series of patient x-ray films that show injuries. The students are asked to ultimately predict the functional outcomes expected for the patient.

STAGE 2. *A laboratory-based experience where small groups of students have an opportunity to* ***generate or analyze data*** *using appropriate tools.*

The students utilized the numerous materials to evaluate an open-source patient x-ray radiographs for fracture sites. Students received normal x-rays with labels, diagrams, and 3-D models to facilitate familiarization, orientation, and to identify fracture sites on the patient x-ray scans.

<u>STAGE 3</u>. *The production of a **tentative argument** that articulates and justifies an explanation on a medium that can be seen by others*.

Using a structured word document (patient analysis form), each group constructed an argument that (1) identifies the skeletal injuries sustained by a "patient" from X-ray scans, (2) using anatomical terminology, provides a locus of pain, (3) proposes impacts to surrounding connective tissue and musculature, and (4) predict impacts to functional movements. Students then synthesized the claims and evidence into a cohesive written paragraph for submission. Students used the relevant structures found in their lab manual to guide their discussion.

<u>STAGE 4</u>. *An **argumentation session** where groups share their arguments and then critique and refine their explanations*.

As the laboratory section has a limited amount of time, and groups naturally finish their patient tentative arguments in varying order and at different times, the lab instructor engaged with each group in the argumentation session. The groups presented their written summary argument and the instructor asked questions afterwards. Students then had the opportunity to correct, clarify, and refine their terminology and logic. During the lab, the instructor guided the students regarding time-constraints, answer questions, and engage in a constructive questioning and critique of each group's argument. The instructor did not provide a didactic lecture.

In the intervention, students completed two in-class group patient analyses each week (Stages 1-4). This study further implement the ADI methodology by adding an out-of-class patient analysis each week that additionally incorporates stages 6, 7, and 8. These stages represent the written peer-review component of ADI which was absent in Study I, but has been shown to be an important contributor in developing scientific literacy (Grooms, Enderle, & Sampson; 2015)

<u>STAGE 6.</u> *A* ***written investigation report*** *generated by individual students that explains the goal of the investigation, the method used, and provides a well-reasoned argument*.

This stage was modified to focus on the students providing a well-reasoned argument to justify their predictions. The students had 48 hours following their lab section to complete and submit their patient analysis.

<u>STAGE 7.</u> *A double-blind* ***peer review of these reports*** *to ensure quality and to generate valuable feedback for the individual authors*.

This stage was modified to be unblinded. Students reviewed members of their individual lab groups through the use of an online discussion board on the course management website (Canvas) and provided a completion grade for their work. The choice to use the discussion board arises from the omission of Stage 5, which is the explicit discussion regarding the lab session, methods, and arguments. Stage 5 is not included due to time-constraints. Instead, the discussion board allowed students to observe the arguments and reviews from other members of their lab section to gain a broader and hopefully deeper, understanding of material. Students was not unable to view the board until after posting their own patient analysis.

The peer reviews followed a rubric that allowed the reader to score the patient analysis in 6 categories:

(1) Complete use of terminology (author included all relevant anatomical terms)
(2) Accurate use of terminology (author used terms correctly)
(3) Complete identification of injured structures (author included all damaged structures)
(4) Reasonable implications for soft tissue (author connected damage to relevant soft tissues)

(5) Evidence to support expected outcomes (author gave evidence for each outcome)
(6) Overall clarity (author wrote clearly and concisely)

The reviewer provided a numerical score for each category from 0 – 4 (0 = absent; 1 = some; 2 = half; 3 = most; 4 = all). In addition to a numerical score, the reviewer also provided the author with comments in each category. The students had 96 hours following the lab section to submit their peer reviews (approximately 48 hours after the patient analyses are due).

STAGE 8. *A subsequent* ***revision*** *of the report based on review feedback*.

The students submitted their revisions by day 6 following the laboratory session; allowing the student to have at least 48 hours to complete the revision after receiving their reviewer's comments. The students completed a patient analysis independently that was subjected to peer review and revisions. The students (a) submitted a patient synopsis (argument) to a designated "reviewer" within their group, (b) provide rubric-guided comments on a patient synopsis, and (c) revise their synopsis based on their own reviewer's comments.

Below is the out-of-class assignment schedule.

Lab Section	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Monday	Lab	Post-Lab Quiz	Summary Paragraph - 1st Draft		Peer Review		Summary Paragraph - Revised

Lab Section	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Monday
Tuesday	Lab	Post-Lab Quiz	Summary Paragraph - 1st Draft		Peer Review		Summary Paragraph - Revised

Lab Section	Wednesday	Thursday	Friday	Saturday	Sunday	Monday	Tuesday
Wednesday	Lab	Post-Lab Quiz	Summary Paragraph - 1st Draft		Peer Review		Summary Paragraph - Revised

Lab Section	Thursday	Friday	Saturday	Sunday	Monday	Tuesday	Wednesday
Thursday	Lab	Post-Lab Quiz	Summary Paragraph - 1st Draft		Peer Review		Summary Paragraph - Revised

This activity was completed independently using a novel set of x-ray scans within the scope of the week's content. Standard ADI methods had the students complete a write-up of the group lab activity; focusing on the processes used, the results, the analyses, and the inferences to develop scientific literacy. However, based on observations from the pilot project, Study II adapted the model for two purposes: (1) allow each student the opportunity to individually practice orienting to the x-ray scan, collecting the data, and formulating their own logic to their argumentation; (2) ensure that students do not simply parrot the process of the other individuals within their group.

Setting

Study II took place in the Applied Human Anatomy Laboratory course over two semesters. This is not a cadaveric dissection lab.

Participants

Study II utilized the consenting students enrolled in the Applied Human Anatomy course over 2 semesters (n = 215). While all students participated in the lessons, only those who provided informed consent provided data for this study. As a result, exclusion from participation only applied to the data of non-consented students and did not restrict their involvement in the laboratory section. Data from students who previously enrolled in the course were excluded. No compensation was provided for participation.

Materials

This study, similar to Study I, leveraged existing technology and learning materials within the lab. The lab was equipped with 47-inch flat screen TV monitors at each lab station. These monitors can display the individual group's computer screen. This allowed students to work collaboratively within their groups. The students received access through the online course management system (Canvas) for:

1. electronic versions of open access patient x-ray radiographs (www.radiopaedia.org),
2. labeled normal x-ray scans,
3. relevant (non-radiograph) labeled diagrams, and
4. a structured word document to guide their data collection and analyses.
5. pre-lab directions
6. lab directions
7. patient analysis and peer review directions
8. a list of lab objectives
9. a list of relevant skeletal structures
10. a list of relevant muscles

These materials were specific to the musculoskeletal system of the appendicular skeleton. The students also had access to 3-D models of all relevant musculoskeletal structures including:

1. Plastic bone models
2. Plastic articulated limbs
3. Articulated skeletons
4. Plastic limb muscle models
5. Plastic joint models with ligaments
6. Plastic joint models with muscles

Each group had the 3-D models at their respective tables and a TV monitor on which to work.

Outcomes & Measures

Outcome 1 was the learning outcomes in anatomical knowledge in non-clinical, lower cognitive demand (i.e., levels 1 and 2 of Bloom's taxonomy) items. The exam was comprised of approximately 100 fill-in-the-blank and multiple choice items targeting the identification and description of anatomical structures and their functions.

Outcome 2 was the application of anatomical knowledge learned without ADI, but assessed following the ADI experience. This outcome was demonstrated through short-answer, free-response items with clinical context that allow the students to engage in more challenging cognitive tasks (i.e., levels 3-5 of Bloom's taxonomy). To measure this outcome, three clinical application questions required the integration of cardiorespiratory content.

Outcome 3 was the application of anatomical knowledge learned within the ADI intervention. This outcome was demonstrated through short-answer, free-response items with clinical context that allow the students to engage in more challenging cognitive tasks (i.e., levels 3-5 of Bloom's taxonomy). This outcome was measured by six items related to the musculoskeletal components of the appendicular skeleton. The three outcomes was assessed via the course midterm and final exams. The exam was paper-based, and combines fill-in-the-blank, short-answer, multiple choice, and true/false. Students had 120 minutes to complete the exam. The lab exam was split into 4 sections:

1. 3D model practical – 20-22 models (60-65 points)
2. PowerPoint histology slide practical – 6-11 slides, (15-25 points)
3. Multiple choice questions – 17-20 questions, (15-20 points).
4. Free response clinical application questions – 4-9 questions, (up to 2 extra credit points)

The students began the exam in the 3D model practical stage, but are able to answer questions from other sections at any time. The histology PowerPoint slides are set to rotate on a 30-second timer.

Example Test Items:

Model:

H. Identify these bony landmarks. ____________________
I. What bone do they articulate with? ____________________
J. What is the name of this joint? _________________

Multiple Choice:

1. Pronation and supination are movements of the ________.
   A) elbow
   B) head
   C) palm of the hand
   D) shoulder

Slide 3: Histology

This is a tissue section from thick skin.

2. What kind of epithelium is the arrow pointing to? ____________________
3. What kind of surface modification does it have? ____________________
4. What would be a possible function for this epithelium? ____________________

Free Response Clinical Application

> Margaret is a 59-year-old female patient admitted to the E.R. after unexpectedly losing consciousness while completing a dare from her friend Ethel, who said that Margaret could not still deadlift 600 pounds at her age. Electrocardiogram tests showed no electrical abnormalities in the heart. Angiogram (vessel scan) studies showed no blockages around the heart or in the blood vessels leading to the brain. Heart rate and blood pressure were normal. Given all these data, explain how a component of the heart might be contributing to Margaret's loss of consciousness. (1 point)

The factual knowledge items were scored by the course instructors according to an exam key developed collaboratively by the instructors. Each instructor was responsible for scoring a specific set of items to ensure consistency. Exam scores were reviewed collectively to ensure the scoring represented the preferred practices of the group. As factual anatomy items carry little variability, the variety of scorers presented little opportunity for bias. The application items were scored by the PI after the completion of the study to allow for blinding of participant, lab section, and condition.

Data Analysis

The data related to the non-clinical items was analyzed using a mixed factorial 2x2 Analysis of Variance with repeated measures on the second factor (RM-ANOVA). The data related to the clinical applications were analyzed using a mixed factorial 2x3 Multivariate Analysis of Variance with repeated measures on the second factor (RM-MANOVA). Follow-up tests was conducted as appropriate.

Chi-square tests of independence was used to determine the equivalence of student distributions across the groups.

Timeline

The study took place over the course of 2 semesters. The first semester acted as the control; carrying out the standard worksheet-based laboratories. The mid-term exam took place following 6 lab sessions (5 content labs and 1 review lab). The final exam followed the same schedule. The intervention labs took place in the second semester. Four of the five content labs following the mid-term exam was argument-driven. The final exam occurred at the end of the semester.

Resources & Funding

This study did not require funding, and leveraged existing material resources in the laboratory space.

Consent Process

The course directors had permitted the study to be implemented as a quality improvement project, meaning that all of the students in the course was completed the laboratory assessments and lab sessions as part of the course. The students were recruited to participate in a departmental study to evaluate the use of ADI in the Applied Human Anatomy lab. They were asked to sign a written informed consent document permitting their academic data to be used for analysis. As the clinical application questions are beyond the typical scope of the course, they were made available as optional extra credit opportunities for all students regardless of participations status.

Limitations

The dissertation used a quasi-experimental methodology in which laboratory sections are assigned to condition. As the condition / grouping variable is confounded by semester, this opens a number of threats to internal validity. This includes threats of calendar-associated differences (e.g., the length and location of academic breaks) between semesters that may extend the period of exposure in one area over another. Sequential groups also receive exposures to different laboratory instructors or the natural maturation and development of the same instructors. The composition (age, sex, motivation, aptitude, etc.) of the groups may vary as well. This is the nature of higher education as it does not easily allow for random assignment to learning strategies. Despite this, the consistency of performance over time in these anatomy labs allows some confidence in the impact of the intervention when it is associated with change from earlier semesters. There is an additional amount of confidence provided by comparisons between scores associated with content that was learned without ADI, but assessed alongside ADI content (e.g., post-test cardiorespiratory clinical applications). Specifically, this provides an additional level of control for group differences in the second half of the semester.

This study was limited to exploring the impact a modified application of the ADI model, and did not include all components of ADI. Therefore, the results of this study cannot speak to the true effect of implementing ADI in the anatomy laboratory. However, as ADI was not been implemented in an undergraduate anatomy course, the results and logistical information gathered informed future implementations. Additionally, as this was a 4-week study, compared to other studies that range from 15-18 weeks, the study was unable to analyze the development of argumentation of the length of the course as other ADI research had.

The post-test assessment of learning outcomes and clinical applications in the undergraduate lab measured with delay to coincide with the laboratory exam schedule required by the larger course. This delay diminished group differences as the students have opportunities to independently enhance their learning in preparation for the exam. The learning outcomes for the undergraduate students was not measured in an immediate pre-post methodology due to the larger course using existing pre-post quizzes. These quizzes were not incorporated for two reasons. First, they were accessible online and had the potential for confounding factors such as using the textbook or an internet search to answer. Second, the questions were solely lower level cognitive tasks that do not demonstrate sufficient variability to provide a fair test of the ADI approach.

While these limitations exist, they were natural challenges to pedagogical research without the full control available to the course instructor. However, the primary purpose of this project was to explore the potential impacts this novel laboratory learning model had in anatomy and potential barriers to its implementation.

Results

The data collected in Study II contained 215 cases. Data were excluded based on being outlying, incomplete, or a repetition. Outliers were defined as cases that scored above the first quartile or below the third quartile by 1.5x the interquartile range of the dependent variable. This resulted in a total case number of 197. The Control condition contained 96 participants, and there were 101 participants in the Intervention condition. Please see Table 5.1 for a full description of the distribution of the participants.

Equivalence of Participants in each Condition

Chi-square tests were conducted to examine associations between independent factors and their distribution within the levels of condition. There was no association between Sex and Condition, $\chi^2(1, 196) = .32$, $p = .57$; indicating that each sex was similarly distributed across conditions. Male and female participants also showed similar proportions of achievement percentiles on the Factual Knowledge pre-test assessment, $\chi^2(7, 196) = 12.71$, $p = .08$ (e.g., 25% of males and 24% of females were in the third quartile of scores). A similar result was found within the distribution of participants according to condition within the Factual Knowledge pre-test achievement percentiles, $\chi^2(7, 196) = 1.88$, $p = .97$ (e.g., 24% of the Control group, and 26% of the Intervention group were in the top quartile). Males and females were similarly distributed across Instructors $\chi^2(3, 196) = 2.42$, $p = .49$.

Factual Knowledge

A Repeated-Measures MANOVA was conducted to test for mean differences in Factual Knowledge scores. There were no significant differences in Factual Knowledge between conditions, $F(1, 185) = 1.192$, $p = .28$, sexes, $F(1, 185) = 2.71$, $p = .10$, nor instructors, $F(3, 185) = 1.124$, $p = .34$. No interaction effects were present between conditions. There was a significant difference between pre-test and post-test Factual Knowledge scores, $F(1, 185) = 37.744$, $p < .001$. Post-test Factual Knowledge scores were significantly higher than pre-test scores by an average of 5.3 points ($p < .001$, $d = .36$). The effect size for this difference was small ($d = .36$). There was also a significant interaction between Sex and Factual Knowledge, $F(1, 185) = 4.565$, $p = .034$. Follow-up tests showed that female students scored significantly higher on average than male students on the pre-test Factual Knowledge assessment by 5.7 points ($p = .032$; $d =$

.34). The difference between male and female scores (mean difference = 1.75) was not significant on the post-test Factual Knowledge assessment (p = .46, d = .02).

Clinical Application

A Repeated-Measures ANOVA was conducted to test for mean differences in Clinical Application scores. There were no main effects according to Sex, Condition, nor Instructor. A significant Condition x Time interaction $F(1, 185) = 15.08$, $p < .001$ was present, along with a significant Sex x Time interaction, $F(1, 185) = 4.78$, $p = .03$. Follow-up tests showed significant differences according to Sex on the pre-test Clinical Application assessment, $F(1, 193) = 4.997$, $p = .027$, with female participants scoring significantly higher on the pre-test Clinical Application assessment by an average of 6.6 points ($p = .03$, d=.33). This difference was not present on the post-test Clinical Application assessment. In addition, there was a significant difference according to Condition on the post-test Clinical Application assessment, $F(1, 193) = 19.071$, $p < .001$, with the intervention group scoring, on average, 12.53 points higher than the Control group on the post-test Clinical Application assessment ($p < .001$, d=.62). This difference was not present on the pre-test assessment. When controlling for Factual Knowledge achievement, there was no significant difference between conditions on the pre-test Clinical Application assessment, $F(1, 196) = 3.09$, $p = .08$. When controlling for Factual Knowledge achievement, there was a significant difference between conditions on the post-test Clinical Application assessment, $F(1, 196) = 17.169$, $p < .001$. Pairwise comparisons showed that the Intervention group scored 10.94 points higher on the post-test Clinical Application assessment ($p < .001$, $d = .54$). When controlling for pre-test Clinical Application achievement in addition to Factual Knowledge, the Intervention group scored 11.95 points higher than the Control group on the post-test Clinical Application assessment. This difference was significant ($p < .001$, $d = .59$) Within-subjects tests showed that the Control group significantly decreased from pre- to post-test for Clinical Application, $F(1, 95) = 22.482$, $p < .001$, $d = .30$. The Intervention group significantly increased from pre- to post-test Clinical Application, $F(1, 100) = 7.94$, $p < .01$, $d = .53$. Chi-square analyses showed that there was not a significant difference between conditions according to their proportion of participants answering the pre-test Clinical Application questions 100% correctly (see Table 5.6.a).

Post-test Clinical Application

The post-test Clinical Application assessment was split into two content components comprising cardiovascular materials and musculoskeletal components. The cardiovascular section represented 30% of the post-test Clinical Application assessment. A Repeated-Measures MANOVA was conducted to test for mean differences in post-test cardiovascular and musculoskeletal Clinical Application scores. No interaction effects were present, and significant main effects were present for Clinical Application assessment $F(1, 185) = 88.56$, $p < .001$, and Condition, $F(1, 185) = 6.65$, $p = .01$. Follow-up tests showed that the Intervention group scored significantly higher (mean difference of 12.1) than the Control group ($p < .001$, $d = .44$) on the cardiovascular content. The Intervention group also scored significantly higher on the musculoskeletal content than the Control group (mean difference of 12.02, $p < .001$, $d = .55$). Both groups scored significantly higher on the musculoskeletal content compared to the cardiovascular content (mean difference of 17.85, $p < .001$, $d = .76$). Chi-square analyses showed that there was a significant difference between conditions according to the proportion of participants that answered the questions 100% correctly. This association was found in 5 of the 9 post-test Clinical Application items.

Instructor Effects

A 3 x 1 ANOVA was conducted to test for mean differences according to instructor, sex, and condition for each assessments. There were no significant differences between instructors on the pre-test factual knowledge assessment $F(2, 185) = .54$, $p = .59$, the post-test factual knowledge assessment $F(2, 185) = .7$, $p = .5$, the pre-test application reasoning assessment $F(2, 185) = .99$, $p = .37$, nor the post-test application reasoning assessment $F(2, 185) = .877$, $p = .42$. The students instructed by the PI in the control and intervention groups did not differ according to factual knowledge on the pre-test ($p = .12$) or post-test ($p = .15$). 3

Discussion

The primary research question of Study II related to assessing quantifiable differences in acquiring factual knowledge and/or clinical application following a 4-week exposure to a modified Argument-Driven Inquiry methodology in the anatomy laboratory. While the intervention did not appear to hinder the ability of students to acquire the course content knowledge, it also did not fully represent an authentic implementation of the ADI methodology. This was the result of a curricular decision made by the laboratory instructor to prohibit the intervention from 1) incorporating components that required protocols that spanned more than one week, 2) decreasing the course content in any way, 3) requiring the other instructors to provide assistance beyond their designated responsibilities, and 4) did not put an undue burden on the students in their out-of-class work. In order to comply with these constraints, the ADI model was pared down to the stages that could be successfully completed within the allotted time, permitted the comprehensive coverage of the designated course content, did not rely on the lab instructors to engage in activities for which they were not trained, and minimized the volume of work required of the students outside of class. Despite the restrictions, the incorporated stages approximated most of the in-class ADI components to demonstrate that anatomy content could be adequately covered in an argument-driven manner. Additionally, the students were able to engage in weekly writing, peer review, and revision. While there were questions from students regarding clarity and desired feedback, the out-of-class components did not seem to burden the students. However, the qualitative analysis of the writing and peer review components was outside the purview of the present study. Future research should assess these factors to gain a better understanding of how well students executed the out-of-class components, and whether improvements can be made to better leverage those activities. Additionally, future research is necessary to test whether ADI can be implemented fully to provide a more robust test of its efficacy in promoting student learning.

In order to answer questions of the intervention’s impact, it was necessary to be able to adequately compare the condition groups. This was a concern as class considerations required the two groups to be assessed in different semesters of the course. Despite the difference in when the groups were assessed, the results indicated that the composition of the conditions were remarkably similar. The two groups possessed similar proportions of the independent factors of Sex, Pre-test Factual Knowledge, Instructors, and Time of Day for the labs. There were more female than male students, at a nearly 2-to-1 ratio, but conditions had similar disparities.

Factual Knowledge

Factual Knowledge was based on an assessment of their ability to accurately identify physical structures of the body. The achievement scores for factual knowledge were similar between groups. The analysis revealed two statistically significant differences. First, the Control group female participants scored higher on the pre-test assessment - a difference that was not present in the post-test assessment. Second, there was an increase from pre- to post-test that was similar across Conditions. This suggests similar learning of factual material in both conditions. In fact, this effect was similar to the effect seen for the Study I lab exams. As such, this appears to reflect the standard level of improvement expected within the course. When considering different components of scientific literacy, the first component is often the acquisition of knowledge (National Research Council, 2005, 2008). It appears that the 4-week modified ADI protocol supported anatomical knowledge acquisition to a similar degree as the standard lab protocol, but no better. While a more positive outcome was expected, these findings align with other ADI research showing that factual knowledge is not impaired compared to traditional laboratory methodologies (Grooms, Enderle, & Sampson, 2015). While a neutral finding, it is important as it addresses the concern that ADI would replace time spent on factual knowledge and, as a result, undermine this component of learning. That these data replicate earlier findings of a neutral impact, they may be used to reduce this concern as a barrier to adoption.

While approaching sciences solely as a body of knowledge (Duschl, Schweingruber, & Shouse, 2007) is a frequent occurrence in science laboratories, this emphasis tends to oversimplify assessments of scientific literacy. A higher-level approach to assessing scientific proficiency should seek to engage in the use of that knowledge, as well as the scientific practices that contextually extend and refine the meaning of that knowledge (Duschl et al., 2007; Sampson, Grooms, & Enderle, 2011). The present study sought to address this by providing short-answer items that required students to recall and apply their knowledge in novel clinical scenarios.

Clinical Application

The Clinical Application assessment was based upon a two-tiered response. First, participants were asked to list, identify, or describe one or more anatomical structures/functions specific to the clinical prompt. Second, the participants were asked to use logical reasoning to develop an answer or hypothesis to explain a phenomenon. For example, one of the pre-test Clinical Application items indicated that “smoker’s cough” was fundamentally due to the damaging effects of smoke on the lining of the respiratory tract. The prompt first asked for the identification of the lining, and then asked for a reason for why this damage would specifically lead to coughing. This scenario was not present within the curriculum and required students to apply their knowledge to develop an answer they had not been formally taught.

The analyses revealed an interesting trend between conditions. While both groups were not statistically different on the pre-test clinical application scores, the post-test scores were approximately 12 points higher in the Intervention group. Even when controlling for pre- and post-test Factual Knowledge and pre-test Clinical Application scores, the moderate effect (d = .51) remained. These results align with other studies showing that reasoning-based performance improved under ADI methodologies - outperforming traditional lab protocols (Sampson, Enderle, Grooms, & Witte, 2011; Grooms, Enderle, & Sampson, 2015). It should be noted that this difference is magnified by the each group’s independent change from pre- to post-test.

The purpose of the post-test Clinical Application assessment was two-fold. First, to gauge the level of application reasoning achieved following standard vs. modified ADI lab protocols. Second, to test for differences in application reasoning related to content materials approached with the standard lab protocol, but tested following the 4 weeks of ADI labs. Following the pre-test midterm exam, the cardiovascular system was covered according to the standard lab protocols. The modified ADI methods were employed on the subsequent 4 weeks of musculoskeletal content. There were three potential outcomes. First, there would be a null effect. Second, there would be an effect, but only for the musculoskeletal application items covered under ADI; supporting a notion that contextual learning mediates the improved application reasoning. Lastly, that there would be an effect for both the cardiovascular and musculoskeletal items. This would support the impact of ADI on reasoning as a transferable skill. The results aligned with third pattern of effects.

For each item of the “non-ADI” post-test Clinical Application section, the Intervention group had nearly triple the proportion of individuals who achieved a 100% correct score; despite the groups having nearly identical levels of Factual Knowledge and pre-test Clinical Application achievement. In fact, both groups possessed nearly identical proportions of attempts for each item. The one exception was a particularly difficult item that was answered 100% correctly by a significantly larger portion of the intervention group, but was attempted by only have the condition. Further analyses are necessary to parse out this finding, but it may be an indication that the Intervention group gained a habit-of-mind that included reasoning in their answers. Without a reason for their answer, the Intervention group may have believed that they could not answer the question at all.

Accuracy of 100% is a useful marker because is only possible to achieve this score if the answer contains a logical conclusion based on an accurate application of factual information. Lower scores can result from: incomplete facts, incorrect terminology, or a reasonable application of the incorrect factual information. The impact was examined within different pre-test percentile scores to ensure that the observed effect was not due to a high proportion of high scoring students at the start of the intervention. While the effect was not present for all participants, nor even a majority, the participants in the Intervention group that achieved the 100% correct score represented a range of knowledge achievement percentile groups.

An important component of application reasoning is the knowledge that provides the foundation for logical reasoning. For example, in order to determine that “smoker’s cough” is the body’s method of clearing respiratory mucus that is building up due to smoke damaging the cilia lining the respiratory tract requires the respondent to know two facts. First, that the lining of the respiratory tract has cilia, and second, that the cilia function to brush mucus away from the lungs. The logical conclusion depends on the activation of that knowledge. The improvement in the Intervention group could be the result of contextual learning supporting more robust retention and accurate retrieval of facts that allowed for correct application of the appropriate knowledge. However, this would not explain the meaningful effect seen in the cardiovascular content items. It may instead be that the process of teaching ADI resulted in a higher level of clinical reasoning. The patient analysis forms used in the laboratory sections guided students through “data collection,” by establishing a series of patient injury facts (fractured bone, dislocated joint, etc.), and then a series of claims that they attempt to support. The logical flow for a patient analysis follows a general pattern of 1) identifying a series of injuries from an x-ray (e.g., fracture of the lateral malleolus of the fibula); 2) considering how that injury might affect soft tissues (e.g., nearby muscle tendons of the fibularis group, and ligaments that attach to the bone at that location); and 3) connecting the disruption of the bone and soft tissues to hypothesize functional outcomes for the individual. These three sections were typically completed as bullet points, and the students communicated their findings and hypothesis in a single, concise, and coherent paragraph. It is likely that this structure, when applied to a novel clinical setting, would result in improved application of factual knowledge for those in the ADI group. If so, it would both explain the superior scores for the musculoskeletal application items for the intervention group and provide support for the broader impact of ADI beyond a given set of materials.

Limitations

This study incorporated phases and components of ADI, but due to logistical and curricular constraints, much of the ADI methodologies required modification. Two modifications are particularly salient to the conversation of reasoning differences within the Intervention group. First, there were no formal argumentation sessions during the lab sessions. While the reasons for this were manifold, it became incumbent upon the individual instructor to engage each group in a smaller discussion related to their patient analysis and their reasoning. It is unknown to what degree each instructor executed this conversation, and to what degree each participant leveraged the opportunity to communicate their understanding, express their reasoning, and receive feedback. The second modification was the out-of-class writing and peer review component. The traditional ADI methodology requires the students to develop a group-written analysis of the lab session; paying particular attention to how the group approached the guiding question, how their methodology sought to test their hypotheses, what cross-cutting concepts were present, and how they justified the evidence they proposed to support their explanation. Each group would have an opportunity to review three other groups' written reports, provide feedback, and then receive feedback on their own. Like the formal argumentation session, this was modified due to time and curricular constraints in the present study. The written component was executed in-class through the group patient analysis form, and out-of-class via an individual patient analysis form. While each participant received the opportunity to participate in their own reasoning and meaning-making out-of-class, it is unknown how well this was accomplished. Together, these modifications might explain why the Intervention group did not experience higher proportions of 100% correct scores.

Without random assignment, threats to internal validity center on differences between groups drawn from different semesters. While a clear risk, the groups did not differ on multiple outcomes: distribution of gender, pre-test knowledge, etc.. Additionally, the two groups possessed similar distributions within each pre-test Factual Knowledge achievement percentile group. This distribution indicates that the distribution of scores were similar and one group was not comprised of a disproportionate amount of high or low-achieving students. The two semesters did differ in one of the laboratory instructors. While the statistical analyses indicated that the Factual Knowledge (pre and post) and pre-test Clinical Application scores did not significantly vary across groups nor across instructors, it is unknown as to what impact the new instructor had on the Intervention group. Unfortunately, there are also unmeasured differences that might exist. For example, there might have been greater motivation for one group over the other. However, both groups attempted a near-identical proportion of each item. The groups also achieved similar proportions of scores on the pre-test Clinical Application assessment, that were completely correct or completely incorrect (either due to not attempting the item or receiving no points for the answer provided). Together, these suggest a similar level of motivation between conditions. Despite this, the Control group regressed at the post-test, scoring 10 points lower on the post-test; contrasting with the Intervention group's increase of 6 points, which might suggest differences in the level of engagement. Another potential limitation is due to other experiences outside of the class that might lead to differential growth. Course offerings differ across semesters and students in one semester might receive more relevant clinical information outside of their anatomy course than those students in another semester. Clearly, future research should replicate this work in a true, cluster randomized control trial to rule out these potential threats to internal validity. Other threats to internal validity derive from potential group differences in knowledge prior to the course. .

There was not a formal psychometric validation of the items used in the assessments. The items were selected based on face validity and alignment with course material. While the Factual Knowledge items seemed to produce reliable results from the Control to the Intervention semester, the Clinical Application items' effectiveness at capturing student reasoning is not well-understood. Further tests of validity are warranted prior to additional research. There was also a potential for bias in the scoring due to only one individual (the PI) scoring the items. While the PI did have several years of experience writing and scoring Clinical Application items, and all of the assessments were scored similarly, any individual item could potentially be scored too conservatively or too liberally, and thereby bias the item. This would become clear with a second scorer. A single scorer often creates bias when they are not blind to condition. To avoid this concern, the PI was blinded to the condition, participant, and lab section for each assessment. As such, there was no concern with this form of bias.

Despite these limitations, ADI possesses a strong theoretical foundation along with literature supporting its positive impact in other scientific disciplines. The results of this study were consistent with other ADI findings, but there is a continued need for additional research on how to most-effectively implement ADI in the human anatomy laboratory. However, until such tests can be conducted, these data do not provide sufficient support for adopting ADI into the anatomy lab

Future Research

As this study was delimited to a quantitative analysis of the differences between standard anatomy lab practices and a modified ADI protocol, it would be a benefit to conduct qualitative analyses of the assessment items and student answers. These analyses may provide greater insight into the nature of the Clinical Application responses. Additionally, future research should explore the group and patient analysis forms generated by the participants. It would be of interest if there is a way to link the group performance to individual performance, and if there are any associations with performance on the assessments. Finally, the modifications made to the ADI methodology in this study were specific to this course. Future studies would benefit from approaching designs that fit within the curricula of other institutions; not only at the university level, but also in professional education. Study III was designed with this goal in mind.

STUDY III

Methods

Design

The third study was a large pilot of a novel anatomy learning opportunity for medical students: cadaver-based medical procedures in the gross anatomy lab. While this pedagogical method appears to have a good fit with the Argument-Driven Inquiry model, it is completely unstudied in the literature. Therefore, it was necessary to gain an understanding of the feasibility of conducting an effective anatomy-focused medical procedures lab, which was then inform the application and implementation of ADI as a guiding framework. As such, this study employed a pre-experimental pre-test/post-test design measuring the impact of a medical procedures learning event on knowledge of professional practices, anatomical knowledge, and student perceptions of learning and professional preparation.

Procedures

Prior to the procedure module, participants completed an online module (videos and readings) related to the professional practices of obtaining informed consent, infection control, and the "time out" process to verify the patient, procedure, and patient side are correct. Participants also underwent a pre-lab readiness assessment that include items related to medical and anatomical knowledge, as well as perceptions of learning and preparedness, confidence, and engagement with faculty, and formation of professional identity. The prompts regarding student perceptions were to be specific to the standard anatomy dissection lab.

In the laboratory, nineteen physician instructors guided and supervise small groups of participants in the clinical implications, relevant anatomy, and practices related to conducting a central venous line procedure, including the use of ultrasound. The physician instructors received a “cheat sheet” of points of emphasis and key information for asking questions of the group. This was intended to decrease the prevalence of overly-didactic activities so that the students had a change to perform the procedure and engage in discussion. The instructors facilitated a student-driven discussion for constructing and supporting ideas to explain the anatomical and clinical connections that drive the reasoning behind medical procedure practices. Following the laboratory, the students underwent a post-assessment identical to the pre-assessment with modifications to the prompts regarding student perceptions, which was specific to the procedure-learning lab event. Additional descriptive analyses were conducted regarding the pre- and post-assessment anatomical knowledge and performance specific to neck anatomy items on the subsequent course exam. Students also had the opportunity to submit free-response feedback regarding experiences and suggestions for improvement.

Setting

This project occurred in the Gross Anatomy Laboratory of a large, selective southeastern medical school.

Participants

The participants were 108 first-year medical students. This intervention was being implemented as a quality improvement activity within the laboratory and all participants engaged in the activity. The participants had the opportunity to provide informed consent and only those who allowed their data to be analyzed for the study. There were no incentives for participation. Benefits include potential improvements in learning outcomes and learning engagement. The risk associated with the central line procedure is the opportunity to poke one's self with a needle. However, the procedure was supervised and guided by a physician instructor. Additionally, the risks of the central line procedure were not greater than the risks associated with the tools used in a standard anatomical dissection.

Outcomes and measures

Outcome 1 was the learning outcomes in anatomical knowledge assessed with multiple choice items and the subsequent course exam, developed by the assistant dean for basic science education and anatomy faculty.

Outcome 2 was the learning outcomes in medical procedure knowledge assessed with multiple choice items developed by assistant dean for clinical education.

Outcome 3 was the students' perceptions of engagement, preparedness, faculty engagement, and professional identity formation assessed with Likert-scale prompts developed by the author and assistant dean for basic science education.

Example item for knowledge of professional practices:

Components of the central line bundle to prevent infection include ALL of the following **EXCEPT**:

A. Handwashing
B. All individuals in the room must wear hat, mask, gowns and gloves
C. Full body drape of the patient
D. Chlorhexidine should be applied in back and forth and up and down
E. Placement in the subclavian vein is the preferred site over the internal jugular as there is generally less risk of infection.

Example item for anatomical knowledge:

Which of the following statements regarding the anatomy of the neck is **MOST ACCURATE**?

A. The external jugular vein is typically found within the carotid sheath in the anterior triangle of the neck just medial to the sternal head of the sternocleidomastoid.
B. The internal jugular vein is typically positioned antero-laterally to the common carotid artery just lateral to the clavicular head of the sternocleidomastoid.

C. The vagus nerve is typically positioned outside of the carotid sheath in the posterior triangle of the neck.
D. The sternocleidomastoid muscle defines the medial boundary of the anterior triangle of the neck.
E. **ALL** of the above statements are accurate.

Example item for student perceptions of learning and professional preparation:
After the standard gross anatomy dissection labs, I feel more prepared for the clerkships next year.

0	1	2	3	4	5
I choose not to answer	I do not Agree	Somewhat Agree	Halfway Agree	Mostly Agree	Completely Agree

Data analysis

Data analyses included descriptive statistics. As there was only 1 group, and it was hypothesized that each dependent variable would improve from the pre- to post-test assessments, all data was analyzed using a 1x7 multivariate analysis of variance with repeated measures on the second factor (RM-MANOVA). Follow-up tests was performed as appropriate.

Timeline

The students had access to the online preparatory materials for 1 week prior to the procedure lab, and was required to complete the online readiness assessment within 48 hours prior to the procedure lab. The immediate post-assessment was due within 24 hours following the procedure lab. The delayed assessment took place with the gross anatomy exam 18 days following the procedure lab.

Resources and funding

Central venous catheterization kits required for the procedural demonstrations was acquired free of charge as surplus medical supplies from the School of Medicine University

Health System REMEDY program. All other aspects of the project was supported via the School of Medicine School of Medicine Office of Curricular Affairs as part of ongoing efforts to assess and improve the medical education program.

Consent Process

The course directors had permitted the study to be implemented as a quality improvement project, meaning that all of the students in the course completed the laboratory assessments and lab sessions as part of the course. The students were recruited to participate in a departmental study to evaluate the use of medical procedure learning in the gross anatomy lab. They were asked to sign a written informed consent document permitting their academic data to be used for analysis.

Limitations

Study III was limited to the exploratory and descriptive results of a novel teaching pedagogy using medical procedures in the gross anatomy lab. Given the lack of a control group, this study cannot speak to causal relationships between the intervention and the learning outcomes. Additionally, a true comparison of student perceptions regarding the standard dissection lab vs. the procedure-learning lab is difficult to make. In the pre-test, the students are asked about their perceptions of learning and professional preparation regarding the standard dissection lab, and this presents a potential problem because they have no exposures to alternative learning experiences. It is unknown if experiencing the procedure-learning lab would re-scale the students' perceptions to show larger differences. Thus, finding no difference between items between the pre- and post-test may not be particularly informative.

It should be noted that the components of the study that diminished an additional assessment of impact (no direct comparison between the labs, the number and structure of assessment items, and the inability to use a random assignment, counterbalanced design to create) resulted from restrictions from the institution and course faculty. While these threats to internal validity exist, they are generally outside the aim of the study to determine the feasibility of a modified ADI approach to the teaching of anatomy in a medical school setting. The logistical and descriptive data gathered was provided valuable insight into executing this novel procedure-based learning within the ADI framework.

Results

These data were collected from 110 first-year medical students enrolled in the gross human anatomy course. Of these, 63 (36 female) provided complete data for the pre- and post-assessments. These participants represented approximately 57% of their respective groups within the total sample.

Factual Knowledge

The Factual Knowledge assessment items were divided into two groups of five questions: (1) medical procedure knowledge and (2) anatomy knowledge. A Pearson correlation test showed that there was no significant relationship between anatomy knowledge and medical procedure knowledge, $r = .06$, $p = .65$. Therefore, separate one-way repeated-measures ANOVAs were conducted to test for mean differences between pre- and post-test, along with interaction effects by Sex.

Medical Procedure Knowledge

The results of the one-way repeated-measures ANOVA showed no significant difference between pre-test (M = 63.49, SD = 23.7) and post-test (M = 64.13, SD = 23.87) factual knowledge scores $F(1, 63) = .06$, $p = .81$, $d = .03$. There was no significant main effects of Sex, $F(1, 63) = .24$, $p = .62$, $d = .03$. Neither was the interaction significant. For each repeated pre- and post-test item pair, a chi-square test of independence was performed to assess if any of the items showed learning changes. All five item pairs showed significant associations between pre- and post-test item score at $\alpha < .05$, which indicated that students did not generally change their answers from the pre-test.

Anatomy Knowledge

The results of the one-way repeated-measures ANOVA showed the difference between pre-test (M = 52.58, SD = 25.81) and post-test (M = 56.55, SD = 24.78) Anatomy Knowledge approached significance, $F(1, 61) = 3.47$, $p = .07$, $d = .16$. There was no significant main effect of Sex, $F(1, 61) = 2.66$, $p = .11$, $d = .03$. For each repeated pre- and post-test item pair, a chi-square test of independence was performed to assess if any of the items showed learning changes. The chi-square analyses showed that all five pre-test anatomy knowledge items were significantly associated with their respective post-test items at $\alpha < .05$, which indicated that students did not generally change their answers from the pre-test.

Student Perceptions

Student Perception items were divided into four categories: (1) learning engagement, (2) preparation for the clinical clerkships, (3) vertical integration between anatomy and clinical practice, and (4) professional identity development. Items asked students to rate the level to which they agreed with each prompt. A 1 x 8 factorial MANOVA was conducted to test for mean differences in students' perceptions. The results showed that there was a significant difference among perceptions, $F(7, 54) = 271.88$, $p < .001$, but there was no main effect by Sex, $F(1, 60) = 1.23$, $p = .27$. No interaction effect was present.

Engagement

A one-way repeated-measures ANOVA was conducted to test for mean differences between pre- and post-test Engagement. The results showed that students reported significantly higher levels of agreement that the medical procedure lab was engaging ($M = 80.24$, $SD = 17.61$) compared to the standard gross anatomy dissection lab ($M = 93.55$, $SD = 15.64$), $F(1, 60) = 21.72$, $p < .001$, $d = .8$. There was no significant difference according to Sex, $F(1, 60) = .01$, $p = .94$, $d = .01$ and no interaction effect was present. Overall, 53% (n = 33) of respondents reporting higher levels of agreement that the medical procedure lab was engaging compared to the standard gross anatomy dissection lab, with 40% (n = 25) reporting no difference, and 7% (n = 4) reporting lower levels.

Preparation

A one-way repeated-measures ANOVA was conducted to test for mean differences between pre- and post-test perceptions of Preparation. The results showed that there was a s significant difference between pre- ($M = 47.38$, $SD = 23.86$) and post-test ($M = 69.96$, $SD = 24$) perceptions of Preparation, $F(1, 60) = 50.121$, $p < .001$. The effect size of this difference was large ($d = .94$). There was no main effect of Sex, $F(1, 60) = 2.12$, $p = .15$. No interaction effect was present. Overall, 74% (n = 46) of participants reported higher levels of perceived

Preparation following the medical procedure lab compared to the standard gross anatomy dissection lab, 18% (n = 11) reported the same levels, and 8% (n = 5) reported lower levels.

Vertical Integration

A one-way repeated-measures ANOVA was conducted to test for mean differences between pre- and post-test perceptions of Vertical Integration of the anatomy content and clinical practices. The results showed that there was a significant difference between pre- ($M = 40.93$, $SD = 26.31$) and post-test ($M = 78.23$, $SD = 23.84$) perceptions of Vertical Integration $F(1, 60) = 90.26$, $p < .001$, $d = 1.49$. There was no main effect of Sex, $F(1, 60) = 1.02$, $p = .32$. No interaction effect was present. Overall, 84% (n = 52) of participants reported higher levels of perceived Vertical Integration following the medical procedure lab compared to the standard gross anatomy dissection lab, 11% (n = 7) reported the same levels, and 5% (n = 3) reported lower levels.

Professional Identity Development

A one-way repeated-measures ANOVA was conducted to test for mean differences between pre- and post-test perceptions of Professional Identity Development. The results showed that there was a significant difference between pre- ($M = 48.39$, $SD = 29.98$) and post-test ($M = 82.26$, $SD = 25.76$) perceptions of Professional Identity Development, $F(1, 60) = 57.83$, $p < .001$, $d = 1.22$. There was no main effect of Sex, $F(1, 60) = 1.0$, $p = .32$. No interaction effect was present. Overall, 73% (n = 45) of participants reported higher levels of perceived Professional Identity Development following the medical procedure lab compared to the standard gross anatomy dissection lab, 21% (n = 11) reported the same levels, and 6% (n = 4) reported lower levels.

Discussion

This study sought to pilot a novel approach that incorporated medical procedure learning in the gross anatomy laboratory of a first-year medical curriculum. The study assessed the impact of this approach on factual knowledge that is both medical procedure and anatomy knowledge, along with student perceptions of this approach vs more traditional anatomy instructional approaches. Any learning activity should be primarily designed to support knowledge acquisition and retention. The results of this study indicate that the use of a medical procedure within the lab did not impact factual knowledge related to the medical procedure, nor did it impact the factual knowledge related to the relevant anatomy of the medical procedure. . It might be that medical students had sufficient baseline learning of anatomy that these data represent some kind of ceiling effect or in which the effect is obscured by their having reached the upper limit of knowledge. This, however, was not the case. In fact, neither category of factual knowledge reached educationally satisfactory levels at the pre- or the post-test. This indicates that an anatomy lab built solely around a medical case study is insufficient to increase anatomical knowledge; nor, did it advance knowledge of medical procedures. As such, this study suggests that an ADI approach to medical education, as taught through medical procedures, is not sufficient for the teaching of anatomy in this setting. Further research should be conducted to determine if it could be modified to improve the educational outcomes or if an ADI approach might provide a useful adjunct or review of traditional anatomy laboratories. Until such studies can be conducted, these data do not support the adoption of ADI into a first-year medical gross anatomy lab.

As the governing bodies of medical education, the American Medical Association (AMA) and American Association of Medical Colleges (AAMC) provide holistic guidance and specific mandates for medical schools in the United States. Prior to this study, the AMA published a large-scale guidance on education reform (Irby, Cooke, & O'Brien, 2010), and the participating medical school received specific comments from the AAMC regarding any deficiencies in its curriculum. These centered on: learning engagement, preparation for the clinical clerkships, vertical integration of biomedical sciences and clinical practices, and the development of professional identity. The student perceptions of these aspects of medical education showed large differences between the standard, anatomy lab and the lab based on a medical procedure. Across the four categories, students reported levels of agreement for the medical procedure lab by an average of one standard deviation greater than the standard gross anatomy lab. While there are not historical data related to all four categories, the AAMC collects annual data from graduating students at the partnering institution for this study. These questions ask students to rate the extent to which each biomedical science course helped prepare them for the clinical clerkship. Neither the students in this study, nor those in the past, perceived the traditional, standard lab as being helpful in their preparation for the clinical clerkship year. Overall, the students viewed both lab experiences as highly engaging, but the standard lab never achieved greater than a 48% positive rating in the other three categories. Meanwhile, the procedure lab never scored below a 69% positive ratings. Thus, while the anatomy lab based on a medical procedure did not improve learning, it was sufficient to satisfy several key AMA and

AAMC curricular guidelines at a superior level to the standard gross anatomy lab. This suggests that these goals may be in some conflict and that improvement in one area need not improve other, related goals. Given the importance of anatomical knowledge to the medical professions, new and improved efforts to incorporate medical procedures into the labs would be required prior to any adoption of this approach - especially without more direct training of the instructor to implement the model with greater alignment with the ADI model.

It was unclear to what extent the physician instructors were able to balance engagement, clinical relevance, and the actual learning of anatomy. It may be possible to achieve such balance when conducting a procedural learning activity around a sufficiently focused, small volume of anatomical information. However, anatomy laboratories rarely designate time for such a focused approach, and the adoption of these high-fidelity learning events may be more appropriate as adjuncts to the lab rather than an adopted laboratory methodology. Given the null effect on factual learning, but the tremendous improvement in student perceptions, these events may be better suited to address institutional initiatives targeting those perceptions. Student surveys and feedback carry substantial weight in the accreditation process for medical schools. As such, these events may be better suited to specifically target the broader institutional goals of students' professional development, while diminishing the emphasis on content knowledge.

The second aim of this study was to evaluate the potential for approaching medical procedure learning events through the Argument-Driven Inquiry framework. Utilizing ADI would serve two purposes. First, it could satisfy one of the AMA guidelines for incorporating habits of inquiry into medical education (Irby, Cooke, & O'Brien, 2010). Second, it could provide the procedure labs with a scaffolding that supports student learning in a manner consistent with best practices in science education (NRC, 2012; Grooms, Enderle, & Sampson, 2015). Unfortunately, this study did not provide a strong test of an ADI approach.

There were several challenges with the design of the medical procedure lab. The first was the natural tendency for the session to fall into one of the common pitfalls of science labs: pure demonstration. The physicians teaching the lab spent between 45-60 minutes talking through the relevant medical and anatomical information prior to beginning the procedural component. By the end of the lab, not all of the students performed the procedure. The second challenge was the teacher-centered approach vs. a student-centered approach. The students primarily listened and the physician instructors carried much of the conversational burden. This inability for students to direct and engage their own meaning-making may also explain the lack of impact the procedure lab had on factual knowledge. Even the traditional, gross anatomy lab allows students to participate in the process through interaction with a cadaver. The lack of full-student participation as a result of these two challenges is a significant limitation of this study. The third challenge was the absence of questions that required students to develop and discuss explanations. Because the goal of the lab was to teach the procedure, the insufficient depth of questioning was not surprising. However, the purpose of the lab was not for the first-year medical students to gain proficiency in conducting the procedure. The lab's overarching theme was for the medical students to begin to think like physicians. Unfortunately, the lab protocol, as implemented, did not fully support that aim. It may be possible for the ADI methodology to be incorporated in a way that better utilizes the procedure lab time and resources. While this would require further research for testing, there are spaces where this could be included within the standard medical curriculum.

Ultimately, imbedded in the framework of any learning activity in science should be the development of scientific proficiency. The four strands of science proficiency are 1) Knowing, using, and interpreting scientific explanations of the natural world; 2) Generating and evaluating scientific evidence and explanations; 3) Understanding the nature and development of scientific knowledge; and, 4) Participating productively in scientific practices and discourse (Duschl et al., 2007; NRC, 2012). Neither the university nor the medical school has sufficient time and resources to adequately support the acquisition, retention, and application of all the relevant knowledge within a field. As the body of scientific knowledge continues to grow along with diminished learning time, this inadequacy becomes more salient. By developing scientific proficiency, students have a better skill-set upon which to rely when engaging and adapting to the inevitable novel phenomena within their various environments.

Limitations

The exploratory nature of this study produced several limitations. The study did not include baseline or long-term follow-up assessments. While the focus of the study was the impact of a lab based upon a medical procedure, a baseline assessment of the medical and anatomical factual knowledge would have provided information regarding the effectiveness of the pre-lab materials provided to introduce the students to the medical practices related to the procedure. Additionally, the baseline assessment may have provided insight into how many students engaged the materials, which was unknown. The study design included using the subsequent gross anatomy exam to assess long-term retention of the anatomy factual knowledge. However, the anatomy exam only included one item somewhat related to the relevant anatomy to the procedure. Unfortunately, it was written as a true/false item, and was answered correctly by

96% of the class. It was decided that this item was not sufficient for comparison due to a lack of difficulty and directness regarding the pre- and post-test content.

The study design was not experimental, and therefore, any factual knowledge differences could not be attributed to the sole influence of the procedure lab, nor could the differences be deemed different from a standard lab. Additionally, the number of participants with complete data was slightly over half of the potential sample. It is unknown whether there was a selection bias due to a higher proportion of highly-engaged students within the sample. Finally, the comparisons between the student perceptions of the standard lab and the procedure lab were not made directly. The students rated each independently, and it is unknown whether a direct comparison within each item would have provided different results.

Future Research

This study was an exploratory pilot of a novel medical procedure learning event within the first-year gross anatomy lab of a highly-selective medical school. Medical education is in the midst of large-scale curricular reforms and innovations. Future research will seek to leverage the growing impetus for innovation in order to develop more robust research methodologies to better study the impact of these types of learning activities on the development of learning as well as scientific and medical proficiency.

CHAPTER IV: GENERAL DISCUSSION

INTRODUCTION

Preparation for healthcare careers invariably includes coursework in human anatomy as the backbone to organize, describe, and explain the natural phenomena related to health and disease (Woods, 2007; McCrorie, 2000). In ideal learning environments, science coursework engages inquiry, incorporates reading, writing, discussions, and allows for the generation and critique of arguments (NRC, 2005). These opportunities support learning for comprehension and problem-solving through engagement in authentic professional practices (Woods, Brooks, & Norman, 2007, Sampson & Gleim, 2009). Despite its historically lofty position in life science education, anatomy instruction rarely meets these standards and the quantity and quality of anatomy education has declined in recent decades (Ridenberg & Laitman, 2002; Bergman, Van Der Vleuten, & Scherpbier, 2011; Mitchell & Batty, 2009; Bockers et al., 2010). Anatomy heavily depends on lower-level cognitive tasks such as memorization, identification, and description (Bloom, 1956), and requires modification to achieve the goals of higher order learning while retaining the acquisition of the large volume of factual knowledge. It may be that a new approach to anatomy instruction would allow it to integrate higher-level cognitive tasks.

Argument-Driven Inquiry is a novel model to structure meaningful laboratory learning activities (Sampson & Gleim, 2009; Sampson, Grooms, & Enderle, 2011). The ADI model structures inquiry in the form of argumentation where students generate and support an explanation for a research question. As such, it is geared to improve both scientific literacy and proficiency. To develop their arguments, students in ADI carry out the processes of actual scientists: generate hypotheses, develop and implement investigations, gather and analyze data, communicate and justify ideas in a group-oriented argumentation session, write reports, and engage in peer-review (Sampson & Gleim, 2009). ADI provides a robust framework for learning domain-specific content through the practices of building scientific literacy. The question remains as to whether ADI is appropriate for the teaching of anatomy.

Schools for the health professions bear the responsibility of preparing future clinicians for careers that are heavily reliant on integrating content knowledge throughout reasoning and problem-solving (Campbell, 1987; Miller et al., 2002). To this end, the human cadaver provides a medium to teach medical students a foundation of anatomical knowledge that must then be integrated with clinical practice and medical procedures. As ADI promotes the development of scientific reasoning through engaging laboratory content, it may be an effective guide for cadaver-based medical procedure learning. That is, teaching through clinical procedures may provide the scaffolding to support the organization and application of anatomical knowledge; allowing facts to become practical (Jolly & McDonald, 1989; Kovacs, 1997). However, teaching anatomy through medical procedures has not been demonstrated in the literature. Moreover, and the application of ADI within anatomy is a substantial deviation from current pedagogical approaches. It is not clear how well ADI can be incorporated within anatomy courses or if an ADI approach would increase learning of anatomical content. To this end, the purpose of this dissertation was to explore the feasibility of implementing Argument-Driven Inquiry to human anatomy across different institutional settings to understand the objective impacts and logistical considerations of these experiences.

THE STUDIES

Study I carried out this aim by piloting a modified application of ADI within an undergraduate anatomy lab section while the other sections conducted standard course protocols. The implementation included only the in-class stages that required students to collaboratively develop and support arguments centered on the functional effects of different fractured bones. While it was not based on a medical procedure, per se, the learning experience was built on clinical information. Large-group argumentation, discussion and peer-review were omitted from the ADI process due to time constraints and other practical limitations. The study used the subsequent lab exam to assess differences in factual knowledge between the pilot lab and the standard lab sections. The results showed that there was no significant difference in knowledge achievement between groups. These data indicated that the ADI lab did not improve - nor did it hinder - the acquisition of facts. It was unclear if the pilot lacked a sufficient exposure to ADI practices, or if other factors obscured the ability to observe differences between groups. However, as the small-scale ADI pilot did not diminish achievement of the course learning objectives, the instructors granted permission to implement a larger application of ADI in the following semesters for Study II.

Informed and guided by lessons from the pilot, Study II sought to carry over the in-class argumentation protocols with the addition of the written peer-review process occurring out-of-class. The study was conducted across two semesters. The first semester acted as the control and the subsequent semester acted as the intervention. The control semester carried out standard lab protocols, and the intervention semester was identical except for a four-week application of ADI. Study II used pre- and post-test assessments to examine the impact of both lab protocols on factual knowledge achievement and the ability to integrate factual knowledge within short-answer clinical application scenarios.

Establishing equivalence between the groups was essential to the ability to compare the findings of the two groups without the benefits of randomized control procedures. The groups possessed similar total sample sizes, and demonstrated similar distributions of male and female students across instructors. Both groups showed similar levels of knowledge achievement and application reasoning on the pre-test assessment. Once the groups were determined to be equivalent, the post-test assessments were analyzed. The results showed no difference in factual knowledge between the conditions and the improvement from pre- to post-test mirrored the expected learning improvements seen in Study I. The post-test clinical application assessment contained two sections of items: 1) application of content learned by both groups under standard laboratory procedures and tested after exposure to ADI in the intervention semester; and 2) application of content learned under standard or ADI protocols. The intervention group significantly outperformed the control group on both sections of the post-test application assessment. This indicates a potential carry-over effect wherein reasoning skills and habits learned in ADI may have supported improved application of content learned without ADI. The difference between groups was magnified by the control group scoring significantly lower on the post-test compared to the pre-test, while the intervention group scored significantly higher than the pre-test. The drop in performance for the control participants was surprising and it leaves open the possibility of poor reliability for the assessment.

As anatomy is also a foundational science in medical education, Study III examined the feasibility of incorporating ADI within the human anatomy laboratory within the first-year curriculum of a large medical school. The study examined how students responded to a physician-taught medical procedure in the anatomy lab. Physician-instructors worked with small groups to 1) perform the procedure, 2) learn the professional medical practices and reasoning associated with any invasive procedure, and 3) promote learning the relevant anatomy within its clinical context. Study III used a one-group pre-/post-test design to measure changes in knowledge of anatomy and medical practices following the learning event. Additionally, the assessments included student perceptions of how well the previous, standard anatomy lab and the present, procedure-based lab accomplished broader national and institutional goals. he procedure lab had no effect on student learning for knowledge of anatomy or medical practices. The students rated the procedure lab substantially higher than the standard lab regarding 1) preparation for the clinical clerkships, 2) integration of clinical practices and core science content, and 3) development of a professional identity. Students considered both lab formats to be highly engaging. These data suggest that an ADI-inspired, medical procedure approach to teaching anatomy in medical school is not appropriate. However, there were a number of limitations to the implementation of the protocol.

The intent of the lab was to use the clinical scaffolding of a medical procedure to support student learning by exploring the reciprocating relationship between the reasoning underpinning clinical practices and the relevant anatomy content. This goal was not realized. The physician-instructors received general guidance and a “cheat sheet” of content and questions to facilitate during the lab. Unfortunately, the instructors failed to facilitate a student-driven discussion for constructing and supporting ideas to explain the anatomical and clinical connections that drive the reasoning behind medical procedure practices. Instead, the instructors fell into roles as lecturers and demonstrators. As such, students rarely had opportunities for the hands-on social construction and elaboration of knowledge. In the end, the study was a poor test of the research question regarding the feasibility of incorporating ADI into the medical curriculum’s anatomy lab. Despite these limitations, the lab was well-received by the students and clearly aligned with national and institutional initiatives aimed at advancing science education to better serve the professional development of medical students. As such, future research in this area should focus on improving implementation in order to provide a more robust test of how ADI-inspired approaches may impact student learning.

In summary, while the ADI framework provides science educators with a robust methodology that is theoretically-sound and driven by best practices for promoting scientific literacy, it was not supported within the anatomy laboratory. While the standard approaches to anatomy education used as comparisons throughout this dissertation did not meet the standards for learning environments designed to engage students in authentic scientific practices they equaled or surpassed the ADI-based instruction. As such, there remains a need to explore better instructional methodologies such as ADI but to ensure their impact on learning before recommending implementation. As such, it is imperative to understand the barriers that may hinder implementation. The results of such research may show that anatomy education does not support ADI in its full form and may require institution-specific modifications. Additionally, they may show a more effective use for ADI to be achieved separately from the designated anatomy lab learning time.

This dissertation contained several limitations that impeded the ability to make larger determinations of ADI's efficacy and utility within the anatomy lab. While many of the limitations were inherent to education research, they are also inherent to the nature of this level of foundational research. However, there are modifications to the approach that could provide data from which to make clear decisions. First, this approach could be offered in an elective course designed around selective topics of interest to students. This would bypass the curricular demands and constraints present in a large foundational course such as anatomy. Additionally, the scale at which ADI is addressed could be step-wise such that each stage is thoroughly vetted for feasibility and efficacy prior to implementation. This approach would also allow subsequent stages to require less exploratory research, as the lessons learned in studying each stage will invariably inform all the rest.

CONSIDERATIONS FOR IMPLEMENTING ADI

The shift, logistically, from standard science lab formats to an ADI methodology is a challenge. The shift, philosophically, can be more challenging. This section will discuss various hurdles, benefits, and factors to assess when approaching an ADI implementation. It is important to note that ADI is not a panacea for weaknesses in science education. There are trade-offs at several levels that may be untenable for a course or curriculum, and therefore, may require modifications or alternative frameworks.

Philosophical Considerations & Buy-in

Possibly the greatest challenges for ADI implementation are the cultural and philosophical changes that an instructor must address within themselves, the teaching team, the program of study, and the students. Argument-Driven Inquiry, particularly in anatomical sciences, is a substantially different approach to education; both historically and in the modern classroom. Research in modern anatomy courses has been admonished for insufficiently assessing learning outcomes as defined by the acquisition of content knowledge (Bergman et al., 2011; Bergman et al., 2013), and most systematic reviews require assessments of content knowledge for inclusion (de Jonge et al., 2008; Losco et al., 2017; Estai & Blunt, 2016). While this perspective is not unique to anatomy (Duschl et al., 2007), it is fairly ubiquitous and is most likely due to anatomy's status as a, primarily, taxonomic science. For instructors weighing the pros and cons of implementing ADI, this cultural perspective must be addressed.

In most conversations around ADI, there is the inevitable question, "How will this methodology impact student learning?" The angst underlying this question derives from three fundamental assumptions: 1) the purpose of the classroom is to facilitate learning, 2) learning is defined as the acquisition and retention of content knowledge, and 3) time allotted to activities that do not promote maximum exposure to the content knowledge will hinder learning. Under such assumptions, the ADI framework presents a threat to student learning and, therefore, can meet substantial resistance from instructors. In fact, the first study in this dissertation was a required proof-of-concept investigation to verify that ADI would not negatively impact student learning before a more in-depth study could be attempted. This of course, requires data to support these outcomes. As such, the primary focus of future research will be a more robust assessment of ADI before this barrier can hope to be addressed.

It may benefit instructors to consider the National Research Council's definition of science as "both a body of knowledge and an evidence-based, model-building enterprise that continually extends, refines, and revises knowledge" (Duschl, Schweingruber, & Shouse, 2007). Table 4.1 summarizes some of the national calls for the advancement of science education. Ultimately, the ADI framework requires a substantial amount of buy-in from the instructor as to the purpose of his/her learning environment. The philosophical positions can be summarized by the following two questions:

1) "How much content will be lost to ADI?"
2) "How much content can be covered in ADI?"

If science as content is king, then the full ADI methodology may not provide the return on investment for an instructor. If science is perceived as a skill that requires progressive development, then an instructor may find the decreased content volume to be tolerable.

The instructor is not alone in this reflective process. The ADI methodology also provides a potential culture-shock for students.

There are two major hurdles for students engaged in ADI labs. First is the inherent ambiguity within scientific inquiry. Second is the willingness to engage in the social construction of knowledge and meaning. During the initial ADI labs in Study II, students consistently asked questions about being on the right track, if their answers were correct, and if there would be a review or answer key that provided the right answers. Students did not seem to appreciate that the focus was to be reasonable vs. “right.” Additionally, some students expressed frustration with the clinical application assessments because they had not been taught the answers. It would benefit an instructor to establish, early in the course, that reasoning is a learning objective within the course. As such, students should expect to see novel questions and practices in order to assess progress towards the goal. Managing student expectations may help prevent mounting frustrations asserted over what students deem to be unfair demands. The students further demonstrated their discomfort with ambiguity when, during the open lab hours, they erased their own answers on the structure/function lists in order to copy down the answers on the key. Students would do this even if their answers were correct but phrased differently than the key. If the labs included the ADI components related to the nature and practices of scientific inquiry, there would have been an established culture within the course that permitted students the freedom to generate, refine, and extend their own understanding. Instead, they often discarded their own understanding for the “right” answers. It is possible that the students would have engaged in these practices regardless but it is an observation that may warrant proactive measures to avoid them. This, of course, is an area ripe for future research. That is, how can an instructor create an environment that is conducive to the development of reasoning skills beyond the accumulation of factual knowledge? While there is a robust literature on this for other domains of learning (Sampson & Gleim, 2009; Grooms, Enderle, & Sampson, 2013; Grooms, Sampson, & Carafano, 2012; Sampson, Enderle, Grooms, & Witte, 2013), it has yet to be fully developed for college or graduate study.

The second challenge was the willingness of students to engage in the process of social construction of knowledge and meaning. Instructors may consider the work of Krashen (1982), specifically his theory on the Affective Filter, when approaching the disengaged or unwilling student. According to Krashen, the Affective Filter is a cognitive block that inhibits a person's willingness to attempt an output of some kind. For example, when an individual experiences a negative affective state (e.g., nervous, unsure, etc.), his/her Affective Filter closes and prevents any attempt at expressing their knowledge or understanding. This Affective Filter is readily apparent in social constructivist classrooms. The students who have confidence to engage in the conversation (either because they are confident in their knowledge, or because they are comfortable with their ignorance) tend to carry the bulk of the conversational load (Krashen, 1981). The students who do not have similar confidence tend to find other roles, or they are quick to indicate that they do not know an answer, or that they do not have a perspective. ADI instructors should consider how the culture and practices of the course support a positive learning environment where students can feel confident to express their knowledge and ideas. Without this output, a student may not receive the necessary feedback to refine their understanding and reasoning. If the students can buy-in to the philosophy and practices of the ADI framework, it can be an engaging and enthusiastic learning environment that empowers everyone to teach and learn together. Again, this presents an opportunity for research in testing interventions to improve student responses to ADI-like approaches.

Logistics of Implementation

There are several trade-offs that an instructor should consider when considering if to implement ADI in the anatomy lab. The first is the assessments used in ADI vs. traditional labs.

In a standard anatomy lab, the assessments are low-level cognitive demand items that only require identification and description. As such, the assessments can cover a large volume of content, and the items can be graded with relative quickness depending on the ratio of instructors to assessments. Even if the assessments require students to write their answers, the responses are typically short and obviously correct or incorrect. In ADI, it is recommended to use a combination of assessments to capture the various content and process learning objectives (Sampson, Grooms, & Enderle, 2011). For example, the total number of clinical application responses scored in Study II was 2,800 for a course that averaged around 107 students per semester. A more robust assessment or larger class size could easily achieve that number of items in a single semester. The volume and complexity of the scoring requires a longer grading time, as well as increased training for instructors on how to assess such responses with consistency. While the scoring workload can be distributed, scoring is a significant issue and instructors should consider the resources available as assessments are being designed.

The second trade-off is the course content. The implementation of ADI benefits from time allotted to expectation management, the nature of scientific knowledge and the processes by which it is obtained, revised, and communicated, and how to engage in productive and constructive scientific discourse through argumentation. ADI also focuses on engaging specific content within the broader disciplinary core ideas, and devotes substantial time to the communication of those facts and concepts. It would be plausible to reduce the content of a course by 20-40% to achieve mastery in the ADI framework. The fundamental trade-off in content is breadth vs. depth; deeply understand 60% vs. being familiar with 90%. The choice is not dichotomous, but reasonable expectations tend to tip the scales in one direction or the other.

The instructor may benefit from considering the following series of questions when reviewing the course content:

1) What content in the course is foundational, important, valuable, or accessory?
2) How long does it take to genuinely master that content?
3) How long do students typically have to master that content?
4) What amount of time can the course reasonably allot to mastering that content?

Ultimately, there is no way to accomplish mastery of all content and processes within a single course. It is incumbent upon the instructor to determine an acceptable balance between how much a student should know, and how much a student should know how to do. This likely drives much of the decision making for using ADI. As anatomy is a particularly high density topic that has historically been based on factual knowledge, it might be a poor fit for ADI approaches. In contrast, exercise physiology or motor learning might have less "core content" and more time for development of depth. Given this, it is expected that the openness to adopt of ADI approaches will vary greatly by course type.

Student Workload

An interesting factor that warrants further consideration is the work students will be required to accomplish in and out of the classroom. A standard expectation at the university is for students to engage with the course materials outside of class for approximately three hours for every course credit hour. In Study II, the outside work was divided into pre- and post-lab assignments. The pre-lab time required was estimated at approximately 60-90 minutes. The post-lab time required was estimated at 60-90 minutes. These time requirements for a 4-credit course allowed between 1-2 hours of additional out-of-class work to reach the 12-hour per week expectation. However, instructors may desire to pilot and monitor the time students are spending on the assigned tasks outside of class. Some instructors may wish to provide more freedom and self-direction for students in how they approach the course materials outside of class, and may find the ADI methodology to be overly structured. The case can be made that the additional structure of outside assignments may be more beneficial for students early in their studies, and as the course(s) progress, the nature and structure of the tasks may become more dynamic. In the end, the out-of-class work may depend on the position of the course within the department, balance across courses at each level of study, and how that position influences the learning objectives

FLEXIBLE STRATEGIES FOR IMPLEMENTING ADI

In this dissertation, the ADI methodology could not be fully implemented due to constraints in time and instructor resources. This led to the examination of the relative benefits of the ADI stages in ADI inspired programs vs a full ADI approach. Depending on the chronology of the course, certain elements (e.g., identifying cross-cutting concepts in Stage 1, submitting research design for approval in Stage 2) may become optional. The nature and extent of the argumentation session may be an opportunity for flexibility. In Study II, the students did not have the opportunity to critically evaluate the arguments of other groups. However, in a lab section with five groups, it would have been difficult to accomplish the presentation and critique of all five within the time limits. The explicit discussion was removed for the same reason. However, the data seemed to indicate that this may have been the missing link for the students who did not experience a marked improvement in reasoning following the ADI protocol. For instructors who cannot fully implement ADI due to logistical constraints, the best approach may be to modify rather than remove stages. The flexibility of ADI allows for strategic modifications to emphasize specific components of scientific proficiency, or to progressively introduce the components to better promote mastery.

Healthcare is full of phenomena that require investigative practices. When considering medical procedures, whether diagnostic or interventional, every step provides students with an opportunity to answer “why” and “how” questions to develop explanations and mental models that establish richer connections between the content and how to integrate it within professional reasoning practices. The following section provides an example approach to better execute the procedure lab in this study through ADI that might be used to guide future research.

Stage 1 - Identify the Task & Guiding Question

Consider the need to administer large volumes of interventional fluid medications that cannot use a standard intravenous catheter (IV). The guiding question is, “How can we administer these medications?” The task allows students to engage in several lines of inquiry that rely on cross-cutting concepts such as system models, cause and effect, and structures and functions. Additionally, students can engage in the disciplinary core ideas related to the anatomy and histology of the circulatory system, fluid dynamics, and pharmaceutical-dependent pathophysiology.

Stage 2 - Design Method & Collect Data

Students can develop hypotheses to test using the various resources available. These can include the cadaver, anatomy models, different versions of intravenous catheters, and ultrasound technology. This stage also familiarizes them with the relevant technology, ethical constraints of medical procedure research, and how to design scientific investigations. Following approval, the students are permitted to collect their data.

Stage 3 - Develop Initial Argument

The students will analyze their data and begin building their initial argument for where and how they propose to solve the IV medication problem. Students may make the claim that a solution would be to use a large diameter catheter in the femoral vein because it provides safer and simpler access compared to other sites. They may provide evidence for the ease-of-access claim by citing ultrasound measurements taken from the group that show the femoral vein has the largest diameter-to-depth ratio. The students may provide the rationale for this evidence by reasoning that while there are other veins that are more superficial, and thus easier to visualize, the large diameter of the femoral vein results in a greater fluid volume; providing it with a greater weight and internal pressure which makes it easier to insert a needle into the vessel.

Stage 4 - Argumentation Session

This stage session will allow students to share their arguments with the class, receive critiques, and then provide critiques and questions for other groups. For example, a question may arise for the earlier claim asking the group whether the femoral vein, due to its location in the groin region, presents a greater risk for infection of the catheter site. Additional data can be collected after this stage if a particular criticism or question cannot be answered from the data available. This stage helps students argue from evidence, ask questions, and evaluate and communicate scientific information.

Stage 5 - Explicit & Reflective Discussion

This stage allows students to share what they know about disciplinary core ideas. For example, the best way to take advantage of the circulatory system's natural distribution function is to administer medications into veins, which will then carry the medication to the heart, where it will be distributed to the body. Medications administered into arteries will be carried to tissues only along the branching pattern of the injection site artery. This will slow the distribution throughout the body, or may over-saturate a particular tissue with the medications. The students will discuss how to improve or even rethink their design for the future. The discussion can also incorporate how students used cross-cutting concepts, or the salient concepts related to the nature and development of scientific knowledge.

Stage 6 - Written Investigation Report

This stage can occur outside of the lab session. Each individual will write a report that shares the goal of the investigation, the method used, and his/her final argument. This dedicated written report allows students to learn to write in a scientific manner, and provides a structured and deliberate opportunity for each person to organize information and make meaning from the lab experience.

Stage 7 - Double-Blind Peer Review

This stage can also occur outside of the lab, and is an excellent opportunity for small-group learning. Each team will receive several reports and will provide feedback according to a structured rubric that promotes quality and constructive comments. This also affords students the opportunity to engage in critical evaluation of written scientific arguments.

Stage 8 - Revise & Submit

Each student may revise their report based on the feedback they received, and should consider the comments discussed in the peer review. This stage supports students' development in communicating information in science, as well as how to improve writing based on feedback.

While these example stages offer one of numerous possible methodologies of how medical procedures can be taught in the human anatomy lab, they demonstrate that the ADI framework provides a theoretically-sound scaffolding for the knowledge and reasoning components of student learning. However, it clear that ADI represents a substantial departure from tradition anatomy lab practices. As such, it is essential to further elucidate factors that potentially prevent a thorough examination of ADI's impact on learning in the anatomy laboratory.

Science Proficiency & the Department

A single course, like a single bout of exercise, may stimulate changes in the individual, but if those demands are not consistent and progressively increased over time, then the long-term benefits will not be realized. The challenges that a university department may experience when considering how scientific proficiency is developed within the curriculum may depend on the level of integration within the curriculum. A high level of integration removes two primary barriers to approaching scientific proficiency within the curriculum at-large: sequencing and siloing of courses. If the degree tracks do not possess a cohort-style progression, then it will be difficult to efficiently and effectively divide and conquer scientific proficiency horizontally or longitudinally. Under such circumstances, each course will need to execute the advancement of proficiency individually. Additionally, courses that are siloed from each other may assume content or processes were or will be addressed elsewhere. The curriculum designers may benefit from considering (Table 4.2) Harden's stages of integration (Harden, 2000) as a means of evaluating the extent to which their curriculum is integrated to collaboratively support the development of science proficiency. In an integrated curriculum, the explicit ADI stages can be executed within and across discipline-specific content, and the framework can easily extend outside of the laboratory learning environment. However, the process of integrating a curriculum may not be an option, and implementing ADI in the courses may serve as a reasonable approach for the department. The advantage is that this allows for a lower commitment within each course, thereby reducing the barriers to adoption. At the same time, the spread across courses ensures a full exposure to the ADI approach.

The full penetrance of ADI within a department may seem overly ambitious, or even redundant. Similar considerations occur for other core competencies. After all, writing is valuable but not every course is required to meet the standards for a writing flag. By extension, this perspective may suggest that the development of scientific proficiency be the framework of the core courses, or possibly only the scientifically-oriented courses. Other routes to ADI implementation could include 1) early courses that focus on the nature of scientific inquiry and proficiency for students within the major, 2) longer capstone course that uses ADI to integrate the student's program of study, 3) each course employs ADI as a culminating project within the course. It is unclear whether these approaches would supply the optimal number of exposures for proficiency development, but they may provide instructors and curriculum designers with opportunities to pilot the efficacy of each.

However a curriculum designer decides to approach ADI implementation, careful consideration should be given to the mission of the department and the needs of the students. Reasoning is a fundamental skill that underpins critical thinking (Fig. 4.1) that students will need in professional environments that change quickly and require problem-solving and self-regulation of adaptation and growth (Cutrer et al., 2017). ADI is not the only methodology that fosters scientific proficiency, and curriculum designers should examine the literature around any framework that aligns with best practices in science education.

The Role of Anatomy

Within a medical school or university kinesiology program, it is impossible to avoid anatomy and with good reason. For the physician, the problem, data, and intervention all exist in one place: the human body. For the kinesiologist, the movement being studied is that of the human body. Anatomy provides students with a language, an organization, and a model for studying, understanding, explaining, and manipulating the human body across a variety of applications. Unfortunately, anatomy is typically taught as an extensive list of structures and functions that will receive context and application later in the curriculum. Not only does this approach fail to facilitate deep learning, it wastes an opportunity to engage students in meaningful preparation for the program ahead. As time and resources for robust anatomical study decline, it may behoove programs to consider approaching anatomy in the manner in which it is used throughout the disciplines of kinesiology. Identifying and elaborating the role anatomy plays within kinesiology is similar to a medical school approaching differing specialties to determine how each uses anatomy in its practice. Ultimately, anatomy is used across disciplines for problem-solving; whether in understanding or intervening. Given anatomy's function, the full implementation of ADI may serve as the most effective strategy for engaging in the anatomical content within the broader goals of improving scientific proficiency. However, the data from this dissertation does not support the use of medical procedures as a way to achieve ADI implementation and goals. Thus, while the goals of ADI is of interest, more data on the impact of these approaches on learning at the university-level is required before we can move forward with adoption of ADI.

Following the early stage of the course which focuses on the nature of science, scientific proficiency, and the disciplinary core principles of anatomy, the curriculum could progress through a series of anatomically-relevant kinesiology themes (Table 4.3). For example, these themes could include 1) anatomy in motion; 2) anatomy in health & disease; 3) anatomy and injuries; and 4) anatomy in performance. Within the "anatomy and injuries" theme, the guiding question for an ADI lab could be, "Why do athletes in sports such as baseball, volleyball, and tennis have higher rates of supraspinatus tears compared to other sports?" Within their investigations, students will 1) revisit the anatomical structures of the shoulder; 2) model the movements of the shoulder; 3) observe potential anatomical interactions that can lead to injury; 4) and explain the circumstances under which these injurious anatomical interactions occur. In the end, students acquire the foundational knowledge, extend and refine their understanding, and begin constructing a mental framework of the human body that promotes reasoning-based application, explanation, manipulation, and communication. At this stage in their education, students are not learning to be anatomists, biomechanists, physiologists, or athletic trainers. The hope is that they are developing a set of skills that will help them be successful in any field they choose to pursue.

APPENDIX

Table 3.1. Assessment means and standard deviations by independent variable

IV		Exam 1		Exam 2		Exam 3		Exam 4		Practical 1		Practical 2		Practical 3	
Lab	**N**	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Lab 1	12	88.33	7.71	94.17	4.63	86.83	7.88	88.67	8.15	74.08	14.91	78.08	15.04	83.58	15.74
Lab 2	12	81.17	8.76	89	9.05	78.92	8.61	84.33	10.19	66.04	17.18	69.21	16.05	75.88	13.48
Lab 3	16	83.63	6.97	84.88	11.12	79.44	8.63	83.88	7.71	64.03	15.09	65.44	15.43	71.5	15.69
Lab 4	13	88.31	5.09	87.69	8.35	79.85	9.81	85.85	7	68.81	13.73	72.27	16.99	78.58	16.78
Lab 5	16	86.69	6.18	88.63	7.65	80.94	7.22	81.25	7.66	67.09	14.41	67.41	16.03	70.63	16.83
Lab 6	18	86.28	6.08	89.89	9.09	79.33	10.43	82.22	7.03	65.33	17.84	68.94	17.79	77.06	12.15
Lab 7	16	86.69	7.24	89.75	9.41	84.13	7.5	87	7.16	68.66	15.08	75.22	16.52	77.81	19.33
Instructor															
1	28	85.64	7.54	88.86	9.97	82.61	8.97	85.93	8.12	68.34	15.58	70.86	16.28	76.68	16.57
2	34	86.47	6.04	89.29	8.34	80.09	8.97	81.76	7.23	66.16	16.1	68.22	16.75	74.03	14.68
3	41	85.59	7.57	88.88	8.8	81.24	8.71	85.85	7.98	67.94	14.98	72.52	16.31	77.49	16.61
Sex															
Female	61	84.8	7.59	88.1	8.52	79.92	8.86	83.74	8.38	65.51	14.6	67.54	15.62	72.82	15.94
Male	42	87.48	5.86	90.33	9.37	83.14	8.55	85.67	7.22	70.3	16.24	75.17	16.61	80.93	14.74
Condition															
Control	87	85.75	7.03	88.87	8.85	80.7	9	84.07	8.04	67.24	15.53	69.81	16.32	75.82	15.3
Intervention	16	86.69	7.24	89.75	9.41	84.13	7.5	87	7.16	68.66	15.08	75.22	16.52	77.81	19.33
Time															
Afternoon	53	85.28	7.62	88.6	9.23	81.09	9.08	85.55	8.24	67.93	15.27	70.83	16.12	76.96	15.72
Evening	50	86.54	6.37	89.44	8.6	81.38	8.66	83.44	7.55	66.96	15.67	70.46	16.83	75.24	16.21
Overall															
	103	85.89	7.03	89.01	8.9	81.23	8.84	84.52	7.95	67.46	15.4	70.65	16.39	76.13	15.9

Note: Means are expressed as the percent of the questions answered correctly.

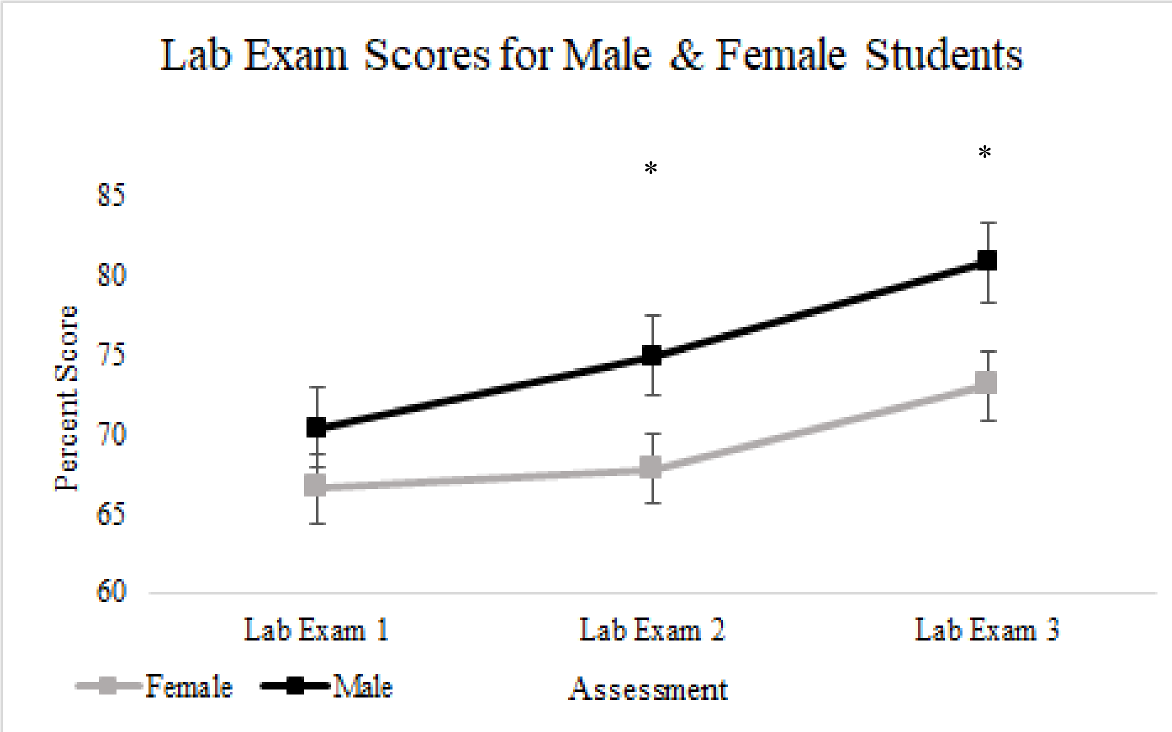
Table 3.2. Study I - Number and proportion of males and females by lab section

	Female (%)	Male (%)
Lab 1	7 (58)	5 (42)
Lab 2	8 (67)	4 (33)
Lab 3	10 (63)	6 (38)
Lab 4	3 (23)	10 (77)
Lab 5	10 (63)	6 (38)
Lab 6	13 (72)	5 (28)
Lab 7	10 (63)	6 (38)
Total	61 (59)	42 (41)

Table 3.3. Number of students by instructor and lab section

		N
Instructor	1.00	28
	2.00	34
	3.00	41
Time	Afternoon	53
	Evening	50

Figure 3.1. Study I - Mean Practical Scores by Sex



Note. * *indicates a statistically significant difference between males and females at p < .05*

Table 3.4. Study II - Distribution of Participants

A. Distribution of Participants by Sex, Condition, and Lab Time

Condition	N	Time	N	Sex	N
Control	96	Afternoon	125	Female	125
Intervention	101	Evening	72	Male	72

B. Distribution of Male and Female Students between Instructors

Control

Instructor	Males (n)	Females (n)	Total (N)	% Male	% Female
1	5	13	18	28	72
2	19	25	44	43	57
3	13	21	34	38	62
Total	37	59	96	39	61

Intervention

Instructor	Males (n)	Females (n)	Total (N)	% Male	% Female
1	4	12	16	25	75
4	17	27	44	39	61
3	14	27	41	34	66
Total	35	66	101	35	65

C. Distribution of Male and Female Students by Condition and Lab Time

Sex	Condition	% Sex within Condition	Afternoon	Evening	Total (N)
Male	Control	51.4	24	13	37
	Intervention	48.6	24	11	35
Female	Control	47.2	37	22	59
	Intervention	52.8	40	26	66

Table 3.5. Pre- and Post-test Means and Standard Deviations for Factual Knowledge

	Pre-test Factual Knowledge			**Post-test Factual Knowledge**		
	Control			Control		
	Male	Female	Total	Male	Female	Total
Mean	68.35*	73.53*	71.54	75.57	74.86	75.14
SD	16.72	14.49	15.51	13.52	14.98	14.36
	Intervention			Intervention		
	Male	Female	Total	Male	Female	Total
Mean	69.43	72.32	71.32	75.93	78.10	77.35
SD	16.74	15.61	15.99	11.26	14.52	13.46
	Total			Total		
	Male	Female	Total	Male	Female	Total
Mean	68.88	72.89	71.42**	75.74	76.57	76.27**
SD	16.62	15.04	15.71	12.39	14.77	13.92

*note: * indicates a significant difference between male and female participants at $p < .05$*

*note: ** indicates a significant difference between pre- and post-test scores at $p < .05$*

Table 3.6. Pre- and Post-test Means and Standard Deviations for Clinical Application

	Pre-test Clinical Application			Post-test Clinical Application		
	Control			**Control**		
	Male	Female	Total	Male	Female	Total
Mean	34.59*	43.39*	40.00 ǂ	28.04	30.77	29.71**
SD	20.32	21.60	21.45	17.32	17.28	17.26
	Intervention			**Intervention**		
	Male	Female	Total	Male	Female	Total
Mean	32.86	37.27	35.74 ǂ	42.50	41.36	41.76**
SD	15.96	20.10	18.81	18.86	22.27	21.06
	Total			**Total**		
	Male	Female	Total	Male	Female	Total
Mean	33.75	40.16	37.82	35.07	36.36	35.89
SD	18.23	20.96	20.20	19.38	20.69	20.18

*note: * indicates a significant difference at p < .05; ** indicates a significant difference at p < .05; ǂ indicates a significant difference between pre-test and post-test score within the same condition at p < .05.*

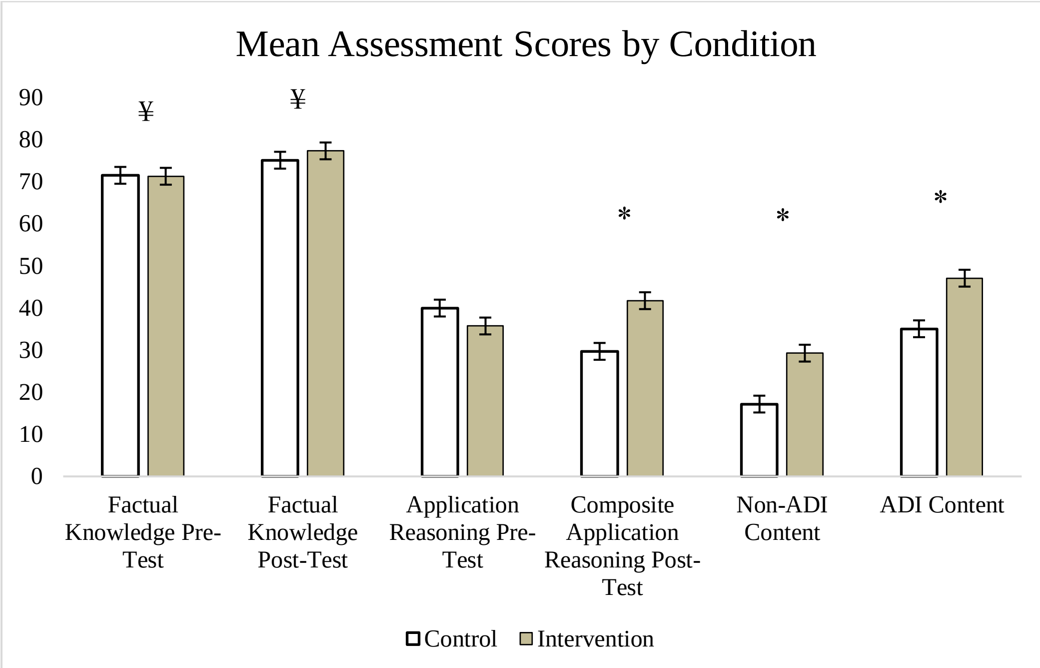
Table 3.7. Male and Female Post-test Application Means and Standard Deviations

Post-test Content	Condition	Sex	Mean	SD
Non-ADI Application	Control	Male	15.99	19.18
		Female	17.94	19.87
		Total	17.19*	19.53
	Intervention	Male	28.10	28.23
		Female	29.92	29.63
		Total	29.29*	29.03
	Total	Male	21.88	24.60
		Female	24.27	26.10
		Total	23.39	25.52
ADI Application	Control	Male	33.20	19.56
		Female	36.26	18.86
		Total	35.08**	19.09
	Intervention	Male	48.67	21.62
		Female	46.27	23.04
		Total	47.10**	22.48
	Total	Male	40.72	21.87
		Female	41.54	21.67
		Total	41.24	21.70

*note: * indicates a significant mean difference at $p < .05$*

*note: ** indicates a significant mean difference at $p < .05$*

Figure.3.2. Mean Assessment Scores by Condition



Note: * *indicates a significant difference between conditions at p < .05;*
¥ *indicates a significant difference from pre-test to post-test at p < .05.*

Table 3.8. Pre-test Clinical Application Question Performance by Condition

	Pre-test Application Q. 1			**Pre-test Application Q. 2**		
Percent Correct	Control Percentage (n)	Intervention Percentage (n)	χ2 Sig.	Control Percentage (n)	Intervention Percentage (n)	χ2 Sig.
0%	45.83 (44)	46.53 (47)		59.38 (57)	79.21 (80)	
100%	11.46 (11)	4.95 (5)	0.10	2.08 (2)	1.98 (2)	0.96
All Others	42.72 (41)	48.51 (49)		38.55 (37)	18.81 (19)	
Attempt	Control Percentage (n)	Intervention Percentage (n)		Control Percentage (n)	Intervention Percentage (n)	
No	16.7 (16)	14.9 (15)		18.8 (18)	16.8 (17)	
Yes	83.3 (80)	85.1 (86)		81.3 (78)	83.2 (84)	
Percent of "zero scores" not attempted	36%	32%		32%	21%	
	Pre-test Application Q. 3			**Pre-test Application Q. 4**		
Percent Correct	Control Percentage (n)	Intervention Percentage (n)	χ2 Sig.	Control Percentage (n)	Intervention Percentage (n)	χ2 Sig.
0%	15.63 (15)	6.93 (7)		16.67 (16)	21.78 (22)	
100%	7.29 (7)	3.96 (4)	0.31	17.71 (17)	13.86 (14)	0.46
All Others	77.08 (74)	89.10 (90)		66.63 (63)	64.35 (65)	
Attempt	Control Percentage (n)	Intervention Percentage (n)		Control Percentage (n)	Intervention Percentage (n)	
No	4.2 (4)	5 (5)		4.2 (4)	6.9 (7)	
Yes	95.8 (92)	95 (96)		95.8 (92)	93.1 (94)	
Percent of "zero scores" not attempted	0.27	0.71		0.25	0.32	

*note: * indicates a significant association between Condition and 100% correct*

Table 3.9a. Post-test Clinical Application Question performance by Condition

	Post-test Application Q. 1 (Non-ADI)			**Post-test Application Q. 2 (Non-ADI)**		
Percent Correct	Control Percentage (n)	Intervention Percentage (n)	$\chi2$ Sig.	Control Percentage (n)	Intervention Percentage (n)	$\chi2$ Sig.
0%	67.71 (65)	60.4 (61)		90.63 (87)	78.22 (79)	
100%	5.21 (5)	13.86 (14)	0.04*	4.17 (4)	13.86 (14)	0.018*
All Others	26.13 (26)	25.74 (26)		5.21 (5)	7.92 (8)	
Attempt	Control Percentage (n)	Intervention Percentage (n)		Control Percentage (n)	Intervention Percentage (n)	
No	25 (24)	22.8 (23)		34.4 (33)	47.5 (48)	
Yes	75 (72)	77.2 (78)		65.6 (63)	52.5 (53)	
Percent of "zero scores" not attempted	0.37	0.38		0.38	0.61	

	Post-test Application Q. 3 (Non-ADI)			**Post-test Application Q. 4 (ADI)**		
Percent Correct	Control Percentage (n)	Intervention Percentage (n)	$\chi2$ Sig.	Control Percentage (n)	Intervention Percentage (n)	$\chi2$ Sig.
0%	62.5 (60)	47.52 (48)		57.29 (55)	34.65 (35)	
100%	11.46 (11)	34.65 (35)	< .001*	5.21 (5)	9.9 (10)	0.22
All Others	26.05 (25)	17.82 (18)		37.68 (36)	55.44 (52)	
Attempt	Control Percentage (n)	Intervention Percentage (n)		Control Percentage (n)	Intervention Percentage (n)	
No	19.8 (19)	18.8 (19)		22.9 (22)	17.8 (18)	
Yes	80.2 (77)	81.2 (82)		77.1 (74)	82.2 (83)	
Percent of "zero scores" not attempted	0.32	0.40		0.40	0.51	

*note: * indicates a significant association between Condition and 100% correct*

Table 3.9b. Post-test Clinical Application Question performance by Condition

	Post-test Application Q. 5 (ADI)			Post-test Application Q. 6 (ADI)		
Percent Correct	Control Percentage (n)	Intervention Percentage (n)	χ2 Sig.	Control Percentage (n)	Intervention Percentage (n)	χ2 Sig.
0%	5.2 (5)	7.9 (8)		40.63 (39)	23.76 (24)	
100%	12.5 (12)	13.9 (14)	0.78	5.21 (5)	27.72 (28)	< .001*
All Others	82.3 (79)	78.2 (79)		54.17 (52)	49 (48.51)	
Attempt	Control Percentage (n)	Intervention Percentage (n)		Control Percentage (n)	Intervention Percentage (n)	
No	5.2 (5)	5.9 (6)		21.9 (21)	16.83 (17)	
Yes	94.8 (91)	94.1 (95)		78.1 (75)	83.2 (84)	
Percent of "zero scores" not attempted	1.00	0.75		0.54	0.71	

	Post-test Application Q. 7 (ADI)			Post-test Application Q. 8 (ADI)		
Percent Correct	Control Percentage (n)	Intervention Percentage (n)	χ2 Sig.	Control Percentage (n)	Intervention Percentage (n)	χ2 Sig.
0%	45.83 (44)	39.6 (40)		42.71 (41)	26.73 (27)	
100%	3.13 (3)	6.93 (7)	0.22	8.33 (8)	44.55 (45)	< .001*
All Others	51.0 (49)	53.47 (54)		48.97 (47)	28.71 (29)	
Attempt	Control Percentage (n)	Intervention Percentage (n)		Control Percentage (n)	Intervention Percentage (n)	
No	31.3 (30)	25.7 (26)		36.5 (35)	24.8 (25)	
Yes	68.8 (66)	74.3 (75)		63.5 (61)	75.2 (76)	
Percent of "zero scores" not attempted	0.68	0.65		0.85	0.93	

Table 3.9c. Post-test Clinical Application Question performance by Condition

	Post-test Application Q. 9 (ADI)		
Percent Correct	Control Percentage (n)	Intervention Percentage (n)	$\chi 2$ Sig.
0%	42.71 (41)	42.71 (41)	
100%	32.29 (31)	31.68 (32)	0.93
All Others	25 (24)	27.72 (28)	
Attempt	Control Percentage (n)	Intervention Percentage (n)	
No	21.9 (21)	22.8 (23)	
Yes	78.1 (75)	77.2 (78)	
Percent of "zero scores" not attempted	0.51	0.56	

*Note: * indicates a significant association between Condition and 100% correct*

Table 3.10. Descriptive Statistics for Factual Knowledge Assessments

Assessment	Sex	Mean	SD	N
Medical Knowledge Pre-Test	Female	64.44	24.43	36
	Male	62.22	23.09	27
	Total	63.49	23.70	63
Medical Knowledge Post-Test	Female	65.56	25.12	36
	Male	62.22	22.42	27
	Total	64.13	23.87	63
Anatomy Knowledge Pre-Test	Female	47.92	23.62	36
	Male	58.80	27.69	27
	Total	52.58	25.81	63
Anatomy Knowledge Post-Test	Female	52.78	23.93	36
	Male	61.57	25.46	27
	Total	56.55	24.78	63

Table 3.11. Medical Knowledge Pre-/Post-Test Item Responses

		Q1 - Post				
		Incorrect	Correct	Total	χ2 sig.	Spearman Correlation
Q1 - Pre	Incorrect	23	4	27	< .001	0.84
	Correct	1	35	36		
	Total	24	39	63		

		Q2 - Post				
		Incorrect	Correct	Total		
Q2 - Pre	Incorrect	10	3	13	< .001	0.71
	Correct	3	47	50		
	Total	13	50	63		

		Q3 - Post				
		Incorrect	Correct	Total		
Q3 - Pre	Incorrect	22	7	29	< .001	0.55
	Correct	7	27	34		
	Total	29	34	63		

		Q4 - Post				
		Incorrect	Correct	Total		
Q4 - Pre	Incorrect	6	5	11	0.014	0.31
	Correct	10	42	52		
	Total	16	47	63		

		Q5 - Post				
		Incorrect	Correct	Total		
Q5 - Pre	Incorrect	24	11	35	< .01	0.43
	Correct	7	21	28		
	Total	31	32	63		

Table 3.12. Anatomy Knowledge Pre-/Post-Test Item Responses

		Q1 - Post				
		Incorrect	Correct	Total	χ2 sig.	Spearman Correlation
Q1 - Pre	Incorrect	13	7	20		
	Correct	2	41	43	< .001	0.66
	Total	15	48	63		
		Q2 - Post				
		Incorrect	Correct	Total		
Q2 - Pre	Incorrect	6	2	8		
	Correct	0	55	55	< .001	0.85
	Total	6	57	63		
		Q3 - Post				
		Incorrect	Correct	Total		
Q3 - Pre	Incorrect	29	4	33		
	Correct	2	28	30	< .001	0.81
	Total	31	32	63		
		Q4 - Post				
		Incorrect	Correct	Total		
Q4 - Pre	Incorrect	41	5	46		
	Correct	0	17	17	< .001	0.83
	Total	41	22	63		
		Q5 - Post				
		Incorrect	Correct	Total		
Q5 - Pre	Incorrect	29	4	33		
	Correct	6	24	30	< .001	0.68
	Total	35	28	63		

Table 3.13. Student Perceptions Means and Standard Deviations

Assessment	Sex	Mean	SD	n
Engagement Pre-Test	Female	80.00	14.60	35
	Male	80.56	21.18	27
	Total	80.24[a]	17.61	62
Engagement Post-Test	Female	93.57	15.27	35
	Male	93.52	16.40	27
	Total	93.55[a]	15.64	62
Clerkship Preparation Pre-Test	Female	42.86	22.54	35
	Male	53.24	24.66	27
	Total	47.38[b]	23.86	62
Clerkship Preparation Post-Test	Female	67.86	23.73	35
	Male	72.69	24.52	27
	Total	69.96[b]	24.00	62
Vertical Integration Pre-Test	Female	37.50	25.72	35
	Male	45.37	26.89	27
	Total	40.93[c]	26.31	62
Vertical Integration Post-Test	Female	77.14	20.89	35
	Male	79.63	27.55	27
	Total	78.23[c]	23.84	62
Professional Identity Development Pre-Test	Female	44.29	29.76	35
	Male	53.70	29.99	27
	Total	48.39[d]	29.98	62
Professional Identity Development Post-Test	Female	81.43	26.67	35
	Male	83.33	25.00	27
	Total	82.26[d]	25.76	62

Note: [a] indicates a significant difference at $\alpha < .05$; [b] indicates a significant difference at $\alpha < .05$; [c] indicates a significant difference at $\alpha < .05$; [d] indicates a significant difference at $\alpha < .05$

Table 4.1. Guidance for Advancing Science & Medical Education

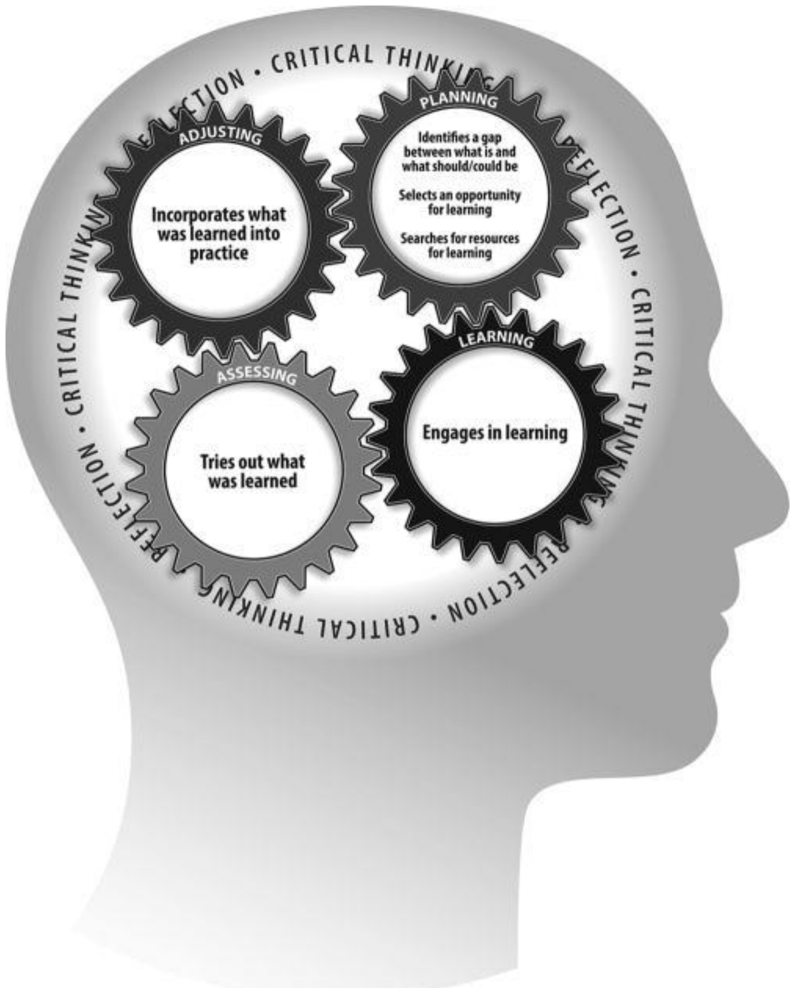
Taking Science to School. National Research Council, 2007	Calls for Reform of Medical Education. Carnegie Foundation for the Advancement of Teaching	Next Generation Science Standards. National Research Council, 2012
Quality science education focuses on four strands of science proficiency	Maximizes flexibility in the process of achieving standardized outcomes	Argumentation from evidence supports understanding of the reasons and empirical evidence for that explanation (p. 44).
1. Knowing, using, and interpreting scientific explanations of the natural world	Creates opportunities for integrative and collaborative learning,	Developing students' deeper understanding of the concepts and practices of science (Grooms, Enderle, & Sampson, 2015)
2. Generating and evaluating scientific evidence and explanations	Inculcates habits of inquiry and improvement	Modeling, developing explanations, and engaging in critique and evaluation (p. 44).
3. Understanding the nature and development of scientific knowledge	Supporting professional identity development	1. Asking questions
4. Participating productively in scientific practices and discourse	(Irby, Cooke, & O'Brien, 2010)	2. Developing and using models;
(Duschl et al., 2007)		3. Planning and carrying out investigations
		4. Analyzing and interpreting data
		5. Using mathematics and computational thinking
		6. Constructing explanations
		7. Engaging in argument from evidence
		8. Obtaining, evaluating, and communicating information (p. 49)
		(NRC, 2012)

Table 4.2. Levels of Curriculum Integration

	Harden's 11 Stages of Integration	
Less Integrated	Isolation	Integration is not explicitly facilitated and is left to students themselves.
↑	Awareness	Teachers avoid duplication across subjects. Integration is left to students themselves.
	Harmonization	Teacher may make some explicit connections within the subject area to other subject areas.
	Nesting	Content from different subjects may be infused to enrich the teaching of one subject.
	Temporal Coordination	Related topics in different subjects are taught concurrently but separately.
	Sharing	Overlapping concepts of different subjects are used as organizing elements for joint teaching of shared concepts in complementary subjects.
	Correlation	An integrated teaching session, course, project, assignment is introduced in addition to the subject-based teaching to bring together related topics.
	Complementary	The integrated sessions now represent a major feature of the curriculum. Running alongside the integrated teaching are scheduled opportunities for subject-based teaching.
	Multidisciplinary	New courses are developed around integrating themes, problems, or issues. The courses may include a structured body of knowledge, which transcends subject boundaries. The theme or problem is the focus for the learning, and the subjects contribute to the students' understanding of the theme or problem.
↓	Interdisciplinary	Content of many subjects, is combined into a new course. There may be no reference to individual disciplines or subjects, and hence a loss of the subject or discipline specific perspectives.
More Integrated	Trans-disciplinary	The curriculum transcends the individual disciplines. The focus for learning is not a theme or topic selected for this purpose, but the field of knowledge as exemplified in the real world.

(Harden, 2000).

Figure 4.1. Critical Thinking & Reflection in Adaptive Learning.



Originally figure 2 from Cutrer et al., 2017

Table 4.3. Themes within Kinesiology

The Nature & Development of Movement	The Interaction between Movement and its Biological Mechanisms	When Movement Goes Wrong	Cognitive & Environmental Support for Performance	Advanced Applications in Performance
Children's Movement	Physiological Basis of Conditioning	Care & Prevention of Athletic Injuries	Theory of Human Performance	Diagnosis and Evaluation of Fitness
Motor Learning	Exercise Physiology	Athletic Training	Fundamentals of Coaching	Personal Training
Children's Physical Activity & Exercise	Neuromuscular Control		Sport Pedagogy	Theory & Practice in Strength Coaching
Motor Development for Performance	Musculoskeletal Functional Anatomy		Sport Psych	Strength & Conditioning Coaching
Biomechanical Analysis of Movement	Sport Nutrition		Coaching Theory & Principles	Disabilities In Sport
				Disabilities & Adaptive Exercise
Applied Biomechanics of Human Movement				
Applied Human Anatomy				

STUDY I MATERIALS

STUDY I

Directions for Clinicals

1) Review the labeled x-rays for each joint prior to attempting the patient analyses.

2) Use the labeled x-rays and your lab manual to help you identify the listed structures from 'Activity 1' on your joint/bone models (do this for the pelvis, femur, knee, tibia, fibula, ankle, and foot).

3) Once you have familiarized yourselves with the x-rays and model anatomy, select 1 patient from each grouping for full analysis (1 each for the pelvis, knee, and ankle/foot). You will need to open a new "Patient Analysis Form" for each patient.

We will be using a "think, pair, share" method when working through the case studies. This is a core component of collaborative learning and encourages communication without wasting a lot of time for every person to talk about every aspect of the case. It works like this:

Your objectives are to:

1) identify the injury (with 'how you know' info)
2) predict the localization of pain
3) predict functional limitations
4) predict soft tissue implications
5) succinctly communicate the above information

1) Open the case study image your group has selected and work alone for about 1-2 minutes jotting down your own notes
2) Pair up within your group and discuss your notes and come to a quasi-concrete conclusion (2-3 minutes)
3) Come together as a group to discuss your data (how they know) and condense your findings and predictions which will be submitted as a group. (5-6 minutes)

4) If time allows, complete #1 and #2 for each of the additional patients.

STUDY I - PAF

Patient Analysis Form

1. <u>Initial data collection</u>

A. Patient ID -

B. Patient Injury – (explain how you know)

2. <u>Interpretations & Expectations</u>

A. Based on the patient's injury, where will their pain be localized?

B. Based on the patient's injury, what are the likely soft-tissue implications?

C. Based on the patient's injury, what are the likely functional outcomes?

D. Explain why you expect these functional outcomes (what evidence?).

STUDY I – POST-Test

NAME: ________________________
UT EID: ________________________
Lab Unique #: ________________________

KIN 324: Applied Human Anatomy
Spring 2016
Lab Practical 1

Part A: Identification - Identify the labeled structures and / or answer the associated questions. Answer only in the space provided, keep answers short and concise, and be as specific as possible. (Total 50 pts)

1.
   A. Identify this organ. __________________________
   B. Which abdominopelvic region does it belong to? __________________________

2.
   C. What is the proper anatomical name for this joint? __________________________
   D. Structurally, what kind of joint is it (be specific – 2 terms)? ________________________
   E. This joint allows for movement in ____ planes so it is __________________________.

3.
   F. What is the proper anatomical name for this joint? __________________________
   G. This joint allows movement in ____ planes so it is called a __________ joint.

4.
   H. What organ is this? __________________________
   I. What organ system it belongs to? __________________________

5.
   J. What is this bony protrusion? __________________________
   K. Name one muscle that originates or inserts here. __________________________

6.
   L. This joint is formed by which 3 articulating bones? _________, __________, _________
   M. Structurally, what kind of joint is it (be specific – 2 terms)? ________________________

7. Articulated Upper Limb (taped with the hand in flexion) -4pts
   N. The muscles responsible for returning this hand to anatomical position are in the _______________ compartment of the _______________.
   O. Where do most of these muscles originate (bony landmark and bone)? __________________________

P. Circle the muscle below that would be responsible for this movement.
Extensor carpi radialis longus / Extensor pollicis brevis / Flexor carpi radialis

8.
Q. What is the primary action of the muscle that originates here?
____
R. How is this muscle unique from the other rotator cuff muscles?
____

9.
S. This fossa accommodates the ________ of the _________ to form part of the elbow joint.
T. What bone does this bony marking articulate with? ___________________________

10.
U. Where does this muscle originate? ___________________________
V. What do all rotator cuff muscles have in common (circle one): primary action, origin, or insertion?

11.
W. This muscle is the prime mover of what movement? ___________________________
X. Name one of its synergistic muscles. ___________________________

12.
Y. Right / Left (circle correct one)
Z. What muscle inserts at this tuberosity? ___________________________

13.
AA. Action: ___________________________
BB. Insertion: ___________________________

14.
CC. What articulates here (bone and bony marking)? ___________________________
DD. This joint, along with its distal counterpart, allows what movement to occur?
____

15.
EE. Name this structure. ___________________________
FF. What function does it perform? ___________________________

16.
GG. This muscle is the prime mover for what movement? ___________________________
HH. Name its antagonistic muscle. ___________________________

17.

II. Right / Left

JJ. List a muscle that inserts at this tubercle? ___________________________

18.

KK. Where is the muscle likely to originate? ___________________________

LL. In general, onto which bones is it likely to insert? ___________________________

19. These are individual bones from the hand and wrist.

MM. Write their names in order from distal to proximal (general names).

20.

NN. What is this proper anatomical name for the top part of this long bone (region superior to the tape)? ___________________

OO. What kind of tissue covers it (be specific – 4 terms)? ______________________________ ____

Part B: Histology - Identify the labeled structures and / or answer the associated questions on the PowerPoint. Be specific when answering (Total 30 pts)

Slide 1:

1. What structure is the arrow pointing at (be specific)? ___________________________
2. What kind of epithelium lines this structure? ___________________________
3. What is its function? ___________________________

Slide 2:

This is a tissue section from the small intestine.

4. What kind of epithelium is the arrow pointing to? ___________________________
5. What would be a possible function for this epithelial layer? ___________________________

Slide 3:

This is a tissue section from thick skin.

6. What kind of epithelium is the arrow pointing to? ___________________________
7. What kind of surface modification does it have? ___________________________
8. What would be a possible function for this epithelium? ___________________________

Slide 4:

9. What kind of connective tissue is occupying most of this slide (be specific – 3 terms)? ____

Slide 5:
10. What kind of tissue is this (be specific – 3 terms)? ___________________________________
____
11. Provide one location where you would find this kind of tissue in the body. _______________
____

Slide 6:
12. What kind of tissue is this (be specific – 2 terms)? ___________________________
13. List one of the structures that are in the center of the osteon? _________________________

Slide 7:
14. What kind of cartilage is this? ___________________________
15. If the term 'articular' cartilage is used to describe the location of this tissue in the body, where is it. ____
16. The perichondrium covers this cartilage and provides structural support. What kind of tissue is it (be specific – 3 terms)? ____

Slide 8:
17. What type of tissue is this? ___________________________
18. Provide one reason for your answer above. ___________________________

Slide 9:
This is skeletal muscle cut in cross-section.
19. Identify this connective tissue 'wrap.' ___________________________
20. Circle the correct structure that is being 'wrapped?'
Myofibril / Muscle Fiber / Fascicle

Slide 10:
21. What kind of cell is this? ___________________________
22. This neuromuscular junction is a 'junction' between which 2 structures? ________________
____
23. What neurotransmitter is released here? ___________________________

__**Part C: Multiple Choice** - (Total 10 points)__
__Circle the most appropriate answer.__

1. Which region is visible only on the posterior/dorsal body surface?
A) buccal
B) calcaneal
C) mammary
D) patellar

2. A patient has a bruise on the ventral surface of the upper limb just distal to the antecubital region. It is located on the ________.
A) anterior arm
B) anterior forearm
C) posterior arm
D) posterior forearm

3. Of the nine regions used by anatomists to divide the abdominopelvic cavity, this one is most superior and medial.
A) epigastric
B) lumbar
C) umbilical
D) hypogastric

4. Which type of section passes through the cranial, vertebral (spinal), thoracic, and abdominopelvic cavities?
A) frontal
B) midsagittal (medial)
C) transverse

5. Which of the following bone belongs to the axial skeleton and is a flat bone?
A) clavicle
B) vertebrae
C) sternum
D) scapula

6. This superficial muscle covers a large part of the posterior thorax.
A) trapezius
B) rectus abdominis
C) rhomboids
D) pectoralis major

7. Which of the following muscle does *not* form part of the rotator cuff?
A) teres minor
B) supraspinatus
C) infraspinatus
D) teres major

8. Extension of the elbow stops when the proximal end of the ulna engages the ________.
A) coronoid fossa of the humerus
B) medial epicondyle of the humerus
C) olecranon fossa of the humerus
D) trochlea of the humerus

9. The thick and thin filaments of muscle are made up of ________, respectively.
A) myosin and actin
B) the dark and light bands
C) the H zone and the Z disc
D) T tubules and terminal cisterns

10. An agonist for forearm flexion is ________, whereas the ________ is an antagonist to this movement.
A) triceps brachii, brachialis
B) brachioradialis, deltoid
C) deltoid, biceps brachii
D) biceps brachii, triceps brachii

Part D: Clinical Applications - Answer the questions below. Answer only in the space provided, keep answers short and concise, and be as specific as possible. If you exceed the space provided the question WILL NOT be graded. (Total 10 pts)

1. (3pts) While performing at the Austin City Limits music festival, Kanye West fell off the front of the stage, and landed on his right arm. As Kanye is being wheeled away to an ambulance, he tries to reassure his 9 fans that he is OK by putting up the 'Hook 'em Horns' sign. However, he is unable to extend his 2nd and 5th phalanges without extreme pain in his elbow. Give the structure that is injured (bone and marking) and explain the pain in his elbow when trying to extend his phalanges.

   ____
   ____
   ____

2. (3 pts) While driving around Los Angeles (trying to find some talent), Nicki Minaj is hit by a large van. The resulting impact leaves her unable to medially rotate her humerus. What muscles has she likely damaged? (Hint; 1 anterior view and 2 posterior view muscles)

   ____
   ____
   ____

3. (2 pts) Athletes in baseball, tennis, and volleyball often develop pain in their shoulder from repeated overhead motions. This happens if they tend to abduct their humerus to throw (baseball) or hit (tennis, volleyball). What skeletal structures are involved in this pain? (include bone and marking).

   ____
   ____

4. (2 pts) Over time, smokers develop a persistent cough known as 'smokers cough.' Cigarettes cause damage to the epithelial lining of the respiratory tract. What epithelium lines the upper respiratory tract, what specific structures are damaged by the cigarettes, and why does this lead to a cough?

   ____
   ____
   ____

STUDY II MATERIALS

Standard Lab Materials

STUDY II – Example Control Group Lab Objectives, Pre-Lab Activities, & Lab Activities

Lab 9

Bones & Muscles of the Pelvic Girdle and the Thigh

Objectives:

1. Identify the bones of the pelvic girdle and know its primary function.
2. Know the important bone markings on the ileum, ischium, pubis, sacrum, and the femur.
3. For each of these bones, identify right from left, inferior from superior view, and anterior from posterior view.
4. Know how to differentiate and explain the differences between a male and female pelves.
5. Be able to identify the major muscles of the pelvic girdle on a lower limb and/or a human plasticized cadaver and know their origin, insertion, and action.
6. Compare the hip joint with the shoulder joint with regards to type of joint, stability, and mobility.
7. Know the classification and the ligaments of the hip joint.

PreLab Activities:
*** Set aside at least 1 hour to complete PreLab activities***
****You will have to show the review sheets at the beginning of lab in order to receive full participation points****
I. Read the following pages in the lab manual AND complete the review sheets. i. Exercise 10: The Appendicular Skeleton, pgs. 155 – 159 i. Complete the review sheets, pgs. 165 – 168 (Start with Qu.7; only do those parts focusing on ileum, ischium, pubis, sacrum, and femur)

ii. Exercise 11: Joints of the Lower Limb, pgs. 178 – 179, and 184
iii. Exercise 13: Gross Anatomy of the Muscular System, pgs. 220 – 223 (starting with Muscles of the Lower Limb - Focus on the tables/figures that have muscles of the pelvic girdle / thigh that match those listed for your muscle cards))
iv. Watch A&P Flix videos in MyLab and Mastering. To access the videos, go to MyLab and Mastering – Study Area – A&P Flix (on the left) – Group Muscle Actions & Joints. Watch the videos in *Unit 4: Muscles that act on the hip joint and femur* and *Unit 5: Muscles that act on the knee joint and lower leg*. While you are watching the videos, make a simple chart that lists the muscles and their major action. Bring the chart with you to lab as a prelab activity to show your instructor. If you click on the video and the screen stays blank – click on the 'red x' in the top right hand corner of your browser and click on 'Load unsafe scripts.' The videos should then load for you.

II. Complete Lab 9: PreLab Quiz on *MyLab and Mastering*.

Materials:

I. ‘Dot’ Stickers

II. Articulated Skeletons

III. Articulated Lower Limbs

IV. Individual Bones (R & L): ileum, ischium, pubis, sacrum, and femur

V. Male and Female Pelves / Rulers

VI. Plastic Lower Limb Muscular Models

VII. Human Cadaver Lower Limbs

VIII. Hip Joint Models

During Lab Group Activities:

Activity 1: Bones of the Pelvic Girdle / Thigh

1. Use the articulated skeletons, the bones & stickers on your desk, and your lab manual to complete this activity; worksheets are posted on Canvas.
2. Make sure you review your bone markings with your instructor when you are done.
3. Remove all stickers and put in trash as part of your clean-up.
4. Show individual, completed worksheets to your instructor.

Study tip: There are bone videos on *MyLab and Mastering.* These are short videos where someone goes over the bones and bone markings that you need to know. A good review option for studying. Click on *MyLab and Mastering* – Study Area – Lab Videos – Bone and Dissection Videos.

Activity 2: Differentiating Female and Male Pelves

1. Use the labeled pelvic girdles at the back of the room and your lab manual to complete this activity.
2. Show the completed worksheet to your instructor.

Activity 3: Identifying Muscles of the Pelvic Girdle and Thigh

1. Use the plastic lower limb muscle models, the human cadaver lower limb models, your lab manual, and the A&P Flix videos to complete the worksheet posted on Canvas.
2. Refer to the numbers / letters on the models to identify the corresponding muscles and answer the questions on the worksheet.
3. Show the completed worksheet to your instructor.

Activity 4: Muscles / Ligaments of the Hip Joint

1. Use the hip joint models, your lab manual (refer to Ex. 11, pgs. 178-179), and the A&P Flix videos to complete the worksheet posted on Canvas.
2. Show the completed worksheet to your instructor.

STUDY II – Example Control Group Lab Activity

Lab 9
Activity 1: Bones of the Pelvic Girdle and Thigh

1. What 3 bones form the pelvic girdle? ____

2. What is the name of the joints between these bones? a. _________________________
b. _________________________

3. What structural / functional type of joints are they (refer to Ex. 11, pg. 184)? a.
____________________: Structural; ____

b. ____________________: Structural; ____

Functional; _______________________________________
Functional; _______________________________________

4. Together, the pelvic girdle along with the coccyx form what deep structure? _____________

5. This structure becomes one with the abdomen and together they become which cavity?
____

6. Name at least 2 organs being protected by the pelvic girdle. __________________________
____

7. What are the 3 regions of the hip bone? a. _________________________
b. _________________________
c. _________________________

8. The femur is the only bone in which region of the body? _____________________________

9. What is a unique feature of the femur compared with all other bones of the body?
____

10. Place the bones on your desk in the correct anatomical order; pay attention to right versus left, inferior versus superior, and anterior versus posterior. Verify with your instructor that you are correct before proceeding. Draw a diagram in the space below with notes so you can remember the orientation of the bones.

STUDY II – Example Standard Lab Activity

Lab 9

Activity 2: Differentiating Female and Male Pelves

Examine the 2 labeled pelves at the back of the room and answer the questions.

1. Using the ruler, measure the pelvic inlet on each of the models (widest point right to left).

A: _______ B: _______

Which pelvic inlet is broadest? _____

2. Describe the shape of the pelvic inlet for each model.

A: ____

B: ____

3. Next, measure the pelvic outlet on each of the models (from ischial spine to ischial spine).

A: ______ B: ______

Which pelvic outlet is broadest? _____

4. Describe the angle of the pubic arch in each model.

A: ____

B: ____

5. On which pelvis are the ilia more laterally positioned? _____

6. Identify which pelves belongs to which gender.

A: ____________________ B: ____________________

7. Which pelvis should be heavier (isn't really reflected in the model)? _____

8. List at least 3 ways you can tell male and female pelves apart.

1. ____
2. ____
3. ____

9. Why are the pelves so different? ____
____

10. The true / false pelvis defines the birth canal.

STUDY II – Standard Lab Activity

Lab 9
Activity 3: Muscles of the Pelvic Girdle and Thigh
Plastic Lower Limb Muscle Model – Identify the numbered muscles on the model.
1. ___________________________
When is this muscle useful clinically? ____
1a. ___________________________
7. ___________________________
What is unique about the insertion site for this muscle? ____________________________
____
8. ___________________________
What is unique about this muscle? ___________________________
Why is this muscle known as the Tailor's muscle? _________________________________
____
9. ___________________________
10. ___________________________
11. ___________________________
12. ___________________________
12a. ___________________________
10-12a:
Collectively, where do all these muscles insert? ____
What action do they perform as a group? ____
Which one of the muscles above also flexes the thigh? How is it able to perform the additional action on the thigh (Hint: How does its origin differ from the others)?
____
Collectively, what compartment of the thigh do these muscles occupy and what are they known as?
____
13. ___________________________
14. Adductor ___________________________
15. Adductor ___________________________
13-15: Collectively, what action do all of these muscles perform? ____________________
Which one of these muscles also flexes the leg? How it is able to perform the additional action on the leg?
____
Which muscle of the medial compartment of the thigh is not included in this group?
____
16. ___________________________
17. ___________________________
18. ___________________________
16-18: Collectively, what actions do these muscles perform?
____
Which of these muscles is most lateral? ___________________________

Collectively, what compartment of the thigh do these muscles occupy and what are they known as?
____

28. _________________________

What effect does this muscle have on the knee? ________________________________

____

Human Cadaver Lower Limb Model -Identify the labeled muscles. For each muscle, add their action along with the bones it originates and inserts on.

A. ___________________________

Origin: _____________________________

Insertion: ___________________________

Action: _____________________________

B. ___________________________

Origin: _____________________________

Insertion: ___________________________

Action: _____________________________

C. ___________________________

Origin: _____________________________

Insertion: ___________________________

Action: _____________________________

D. ___________________________

Origin: _____________________________

Insertion: ___________________________

Action: _____________________________

E. ___________________________

Origin: _____________________________

Insertion: ___________________________

Action: _____________________________

F. ___________________________

Origin: _____________________________

Insertion: ___________________________

Action: _____________________________

G. ___________________________

Origin: _____________________________

Insertion: ___________________________

Action: _____________________________

STUDY II – Standard Lab Activity

Lab 9
Activity 4: Muscles and Ligaments of the Hip Joint
Refer to Ex. 11, pgs. 178-179 in your lab manual.
Which bones / bony landmarks articulate to form the hip joint?
____
____
___
Functionally, what kind of joint is this? _________________________
Structurally, what kind of joint is this (be specific)? _________________________
This joint is _________ axial so it allows movement in _____ planes.
List the 6 possible movements of the thigh.
1. _________________________
2. _________________________
3. _________________________
4. _________________________
5. _________________________
6. _________________________

Ligaments of the Hip Joint (Model A) - Identify the following labeled structures on the model and answer the associated questions.
A. This is a posterior / anterior view of the hip joint.

So, this is a right / left hip joint.
B. Bony landmark: _________________________
C. Bony landmark: _________________________
D. Bony landmark: _________________________
E. _________________________
F. _________________________ ligament
What 2 bones is it attached to? _________________________

G. _________________________ ligament
What 2 bones is it attached to? _________________________
The two ligaments above are on the anterior / posterior side of the hip joint.

H. _________________________ ligament
What 2 bones is it attached to? _________________________
This ligament is on the anterior / posterior side of the hip joint.
What is the name of the short ligament that helps to secure the femur in the socket (not evident on the model)? _________________________

List the two bony landmarks that are joined by this ligament.

____

____

What is the circular rim of fibrocartilage that reinforces this joint called?

____

Lab Materials Available to Both Groups

STUDY II – Example Muscle Flashcard Directions Available on the Course Management Website to all Groups

Flashcards for Muscles of the Pelvic Girdle and Lower Limb

INSTRUCTIONS:

1. Make flashcards with the origin, insertion, and action for the muscles that act on the thigh and leg.
2. Electronic flashcards are acceptable if you can demonstrate you are the author.
3. Use your textbook, lab manual, and/or A&P Flix videos (*on MyLab and Mastering)* as a guide to be sure you are correct. Other on-line sources may provide incorrect answers.
4. An excel spreadsheet is posted on Canvas that has the information simplified compared with what is in the lab manual; you can also use that as a guide to make your flashcards.
5. Flashcards are due at the beginning Lab 10.

Muscles Acting on Thigh and/or Leg (insert onto femur, tibia and/or fibula)

Anterior View (7):

- Iliacus
- Psoas major
- Sartorius
- Rectus femoris
- Vastus lateralis
- Vastus intermedius
- Vastus medius

- Medial View (5):
- Adductor magnus
- Adductor longus
- Adductor brevis
- Pectineus
- Gracilis

- Posterior View (7)
- Gluteus maximus
- Gluteus medius
- Gluteus minimus
- Biceps femoris
- Semitendinosus
- Semimembranosus
- Popliteus

- Lateral View (1)
- Tensor fasciae latae

STUDY II – Example Muscle Card Information Available on Course Management Website for all Groups

Muscle	**Origin**	**Insertion**	**Primary Action**
Anterior and Medial Aspects; Muscles acting on thigh and leg			
Iliacus*	Hip bone; anterior, superior iliac fossa	Femur; lesser trochanter	Thigh flexion
Psoas major*	T12 / Lumbar Vertebrae; transverse processes	Femur; lesser trochanter	Thigh flexion
Sartorius	Hip bone; anterior, superior iliac spine	Tibia; proximal, medial	Thigh flexion, abduction, lateral rotation Leg flexion
Anterior Compartment			
Tensor fasciae latae	Hip bone (ilium); iliac crest, anterior superior iliac spine	Iliotibial band (IT)	Steadies trunk
Rectus femoris^	Hip bone (ilium); anterior, inferior iliac spine	Tibia; tibial tuberosity	Thigh flexion Leg extension
Vastus lateralis^	Femur; greater trochanter, intertrochanteric line, linea aspera	Tibia; tibial tuberosity	Leg extension
Vastus medialis^	Femur; intertrochanteric line, linea aspera	Tibia; tibial tuberosity	Leg extension
Vastus intermedius^	Femur; anterior, lateral surface	Tibia; tibial tuberosity	Leg extension
Medial Compartment			
Adductors - magnus, longus, and brevis	Hip bone; ischium and pubis, inferior edge	Femur; linea aspera , adductor tubercle	Thigh flexion, adduction, and medial rotation
Pectineus	Hip bone; inferior pubis	Femur; inferior to lesser trochanter, linea aspera	Thigh flexion, adduction, and medial rotation
Gracilis	Hip bone; inferior pubis	Tibia; anterior, medial surface	Thigh adduction Leg flexion, medial rotation

Posterior Aspect; Muscles Acting on Thigh and Leg			
Gluteus maximus	Hip bone (ilium); dorsal / sacrum / coccyx	Femur; gluteal tuberosity / IT band	Thigh extension
Gluteus medius	Hip bone (ilium); lateral	Femur; greater trochanter	Thigh abduction, medial rotation
(Gluteus minimus)	Hip bone (ilium); posterior, inferior surface	Femur; greater trochanter	Thigh abduction, medial rotation
Hamstrings			
Biceps femoris (2 heads)	Hip bone; ischial tuberosity / Femur; linea aspera	Tibia; lateral condyle / Fibula; head	Thigh extension Leg flexion
Semitendinosus	Hip bone; ischial tuberosity	Tibia; superior, medial	Thigh extension Leg flexion
Semimembranosus	Hip bone; ischial tuberosity	Tibia; medial condyle / Femur; lateral condyle	Thigh extension Leg flexion
Anterior / Lateral View of the Leg; Muscles acting on foot and toes			
Tibialis anterior	Tibia; lateral condyle, superior	Tarsals; cuneiform / Metatarsal I	Foot; dorsiflexion
Extensor hallicus longus	Fibula; anteromedial shaft	Great toe; distal phalanx	Great toe extension
Extensor digitorum longus	Tibia; lateral condyle, superior	Toes; 2-5	Toe extension (PM)
Fibularis tertius	Fibula; anterior, distal shaft	Metatarsal V	Foot; dorsiflexion, eversion
Fibularis longus	Fibula; head, superior shaft	Tarsals; medial cuneiform / Metatarsal I	Foot; plantar flexion, eversion
Fibularis brevis	Fibula; distal shaft	Metatarsal V	Foot; plantar flexion, eversion

Posterior View of the Leg; Muscles acting on foot and toes			
Triceps surae (common tendon, shape the calf)+			
Gastrocnemius (2 heads)+	Femur; medial and lateral condyles	Tarsal; calcaneus / Leg flexion when foot is dorsiflexed	Foot; plantar flexion
Soleus+	Tibia; proximal shaft / Fibular; proximal shaft	Tarsal; calcaneus	Foot; plantar flexion
Popliteus	Femur; lateral condyle / Meniscus; lateral	Tibia; Proximal	Leg flexion, medial rotation ('unlocks knee')
Tibialis posterior	Tibia; superior shaft / Fibula; superior shaft	Tarsals / Metatarsals II - IV	Foot inversion Stabilizes longitudinal arch
Flexor hallicus longus	Fibula; middle shaft	Great toe; distal phalanx	Foot; plantar flexion, inversion Great toe flexion
Flexor digitorum longus	Tibia; posterior surface	Toes 2-5; distal phalanges	Foot; plantar flexion, inversion Toe flexion

Iliopsoas (share a common tendon)*
Quadriceps femoris (share a common tendon)^

ADI Lab Materials

STUDY II – Example Pre-Lab Activities - Intervention

PRE-LAB ACTIVITIES

* Set aside at least 1 hour to complete PreLab activities
**You will have to show the review sheets at the beginning of lab in order to receive full participation points

I. Read the following pages in the lab manual AND complete the review sheets.

i. Exercise 10: The Appendicular Skeleton, pgs. 155 – 159

- Complete the review sheets, pgs. 165 – 168
    - (Start with Qu.7; only do those parts focusing on ileum, ischium, pubis, sacrum, and femur)

ii. Exercise 11: Joints of the Lower Limb, pgs. 178 – 179, and 184

iii. Exercise 13: Gross Anatomy of the Muscular System, pgs. 220 – 223 (starting with Muscles of the Lower Limb - Focus on the tables/figures that have muscles of the pelvic girdle / thigh that match those listed for your muscle cards)

iv. Watch A&P Flix videos in MyLab and Mastering. To access the videos, go to MyLab and Mastering – Study Area – A&P Flix (on the left) – Group Muscle Actions & Joints.

- Watch the videos in Unit 4: Muscles that act on the hip joint and femur and Unit 5: Muscles that act on the knee joint and lower leg.
- While you are watching the videos, make a simple chart that lists the muscles and their major action. Bring the chart with you to lab as a prelab activity to show your instructor.

If you click on the video and the screen stays blank – click on the 'red x' in the top right hand corner of your browser and click on 'Load unsafe scripts.' The videos should then load for you.

II. Complete the STRUCTURE/FUNCTION LIST and the MUSCLE LIST for LAB 9. You can find these in the Master Section – Lab materials – Lab 9 – Print Materials for Lab.

III. Complete Lab 9: PreLab Quiz on MyLab and Mastering.

STUDY II – Example Objectives for Intervention Lab

LAB 9 OBJECTIVES

1. Describe the structure of the **Pelvis**.
    a. List the 4 bones of the pelvis.
    b. Identify the 3 bones of the "Os Cox" or "Coxal bone."
    c. Describe the articulations of the 4 bones of the pelvis, and provide the anatomical name(s).
    d. Describe the anatomical differences between the male and female pelvis.
    e. Identify the pelvic "inlet" and the pelvic "outlet."
    f. Identify the structural and functional classifications of pelvic joints.
2. Describe the structure of the **Iliac bone**.
    a. Identify the bony landmarks that act as articulations sites for other bones.
    b. Identify the bony landmarks that act as **origins** for muscles.
    c. Identify the bony landmarks that act as **insertions** for muscles.
    d. Identify the bony landmarks that provide additional functions beyond articulations and muscle attachment sites.
3. Describe the structure of the **Pubis bone**.
    a. Identify the bony landmarks that act as articulations sites for other bones.
    b. Identify the bony landmarks that act as **origins** for muscles.
    c. Identify the bony landmarks that provide additional functions beyond articulations and muscle attachment sites.
4. Describe the structure of the **Ischium bone**.
    a. Identify the bony landmarks that act as articulations sites for other bones.
    b. Identify the bony landmarks that act as **origins** for muscles.
    c. Identify the bony landmarks that provide additional functions beyond articulations and muscle attachment sites.
5. Describe the structure of the **hip joint.**
    a. Describe how the femur articulates with the pelvis.
    b. List and identify the ligaments and labrum that stabilize the hip joint.
    c. Identify the structural and functional classification of the hip joint.
6. Describe the structures of the **proximal femur.**
    a. Identify the bony landmarks that act as articulations sites for other bones.
    b. Identify the bony landmarks that act as **origins** for muscles.
    c. Identify the bony landmarks that act as **insertions** for muscles.
    d. Identify the bony landmarks that provide additional functions beyond articulations and muscle attachment sites.

STUDY II – Example Directions for the Intervention Lab

LAB 9: Directions

Structure:

I. INSTRUCTOR REVIEW (15-20 minutes)

- Lab 7 post-lab quiz
- Patient summary paragraphs (x2)
- Peer review (x1)

II. GROUP PATIENT ANALYSIS (70 minutes)

***** ON ALL SCANS, IDENTIFY MALE VS. FEMALE PELVIS *****

- Pelvis Patient (x1) – Submit to Canvas (assignments)
- Hip Patient (x1) – Submit to Canvas (assignments)
- ***Check off structures on your structure/function list and your muscle list as you include them in your analysis***

III. MODEL TIME! (30 minutes) – No, you may not leave early. Learn stuff.

- Quiz each other
- Identify structures not discussed in patient analysis
- Ask yourself the following questions:
  - What am I looking at?
  - What does that do?
  - How can the instructors try to trick me?

*** MAKE SURE TO DISCUSS MODELS WITH YOUR INSTRUCTOR ***

Helpful Hints & Keys to Success:

1. Start with the question, "What am I looking at?"
2. Follow that with the question, "What does that do?"
3. Finish that series of questions with, "How does that fit into the function of the joint?"
4. When "EXPLAINING" anything, **provide evidence** (how you know) to show how you got to your answer.
5. Before you finish, always ask the questions:
   I. Is this accurate? (Is everything I said true?)
   II. Is this complete? (Did I include all the relevant information?)
   III. Did I use all of the relevant anatomical terms?
   IV. Did I support my claims with evidence?
   V. Did I communicate clearly and succinctly?

STUDY II – Example Structure/Function List for the Intervention Lab

LAB 9: Structure/Function List

For each structure, there is a box for you to identify the function of that structure. If there is no clear function, provide a description. **When you are in lab, identify them on the models provided.**

1. ILIUM

Structure	Function (if no clear function, provide a description)
Iliac Crest	
Iliac Fossa	
Gluteal Surface	
Anterior Superior Iliac Spine	
Anterior Inferior Iliac Spine	
Posterior Superior Iliac Spine	
Posterior Inferior Iliac Spine	
Greater Sciatic Notch	
Sacroiliac Joint	
Acetabulum (Iliac Portion)	

2. ISCHIUM

Structure	Function (if no clear function, provide a description)
Ischial Tuberosity	
Ischial Spine	
Ischial Labrum	
Ischial Ramus	
Acetabulum (Ischial Portion)	

3. PUBIS

Structure	Function (if no clear function, provide a description)
Pubic Symphosis	
Superior Pubic Ramus	
Inferior Pubic Ramus	
Acetabulum (Pubic Portion)	

4. COXAL BONE (Ilium, Ischium, and Pubis combined)

Structure	Function (if no clear function, provide a description)
Acetabulum	
Acetabular Notch	
Acetabular Fossa	
Obturator Foramen	

5. WHOLE PELVIS

Structure	Function **(Also, differentiate between male & female)**
Pelvic Inlet & (male vs. female)	
Pelvic Outlet & (male vs. female)	
Pubic Arch & (male vs. female)	
False Pelvis	
True Pelvis	
Pelvic Brim	

6. CONNECTIVE TISSUES OF THE PELVIS

Structure	Function (if no clear function, provide a description)
Acetabular Labrum	
Ligamentum Teres (Ligament of the head of the femur)	
Joint Capsule	
Iliofemoral Ligament	
Ischiofemoral Ligament	
Pubofemoral Ligament	

7. SACRUM

Structure	Function (if no clear function, provide a description)
Sacral Crest	
Auricular Surface	

8. PROXIMAL FEMUR

Structure	Function (if no clear function, provide a description)
Head	
Fovea Capitis	
Neck	
Greater Trochanter	
Lesser Trochanter	
Intertrochanteric Crest	
Intertrochanteric Line	
Gluteal Tuberosity	

STUDY II – Example Muscle List for the Intervention Lab

LAB 9:
Muscles that Move the Femur and Leg

1. Anterior View

Muscle	Action
Iliacus	
Psoas Major	
Iliopsoas	
Sartorius	
Rectus Femoris	
Vastus Lateralis	
Vastus Intermedius	
Vastus Medius	

2. Medial View

Muscle	Action
Adductor Magnus	
Adductor Longus	
Adductor Brevis	
Pectineus	
Gracilis	

3. Posterior View

Muscle	Action
Gluteus Maximus	
Gluteus Medius	
Gluteus Minimus	
Piriformis	
Gemellus (superior & inferior)	
Obturator Internis	
Quadratus Femoris	
Biceps Femoris	
Semitendinosus	
Semimembranosus	
Popliteus	

4. Lateral View

Muscle	Action
Tensor Fascia Latae	

STUDY II
STUDY II – Instructions for the Patient Analysis & Peer Reviews for the Intervention

PATIENT ANALYSIS & PEER REVIEW DIRECTIONS

Purpose:
The purpose of this exercise is to give you the opportunity to demonstrate the ability to progress through our adapted clinician's processes on your own. Additionally, this process will allow you to learn through reading and editing patient analysis forms from your classmates in a double-blind (neither person knows) review. Finally, you will learn through receiving feedback on your analysis form and revising it.
Directions:

- On your own (without help or input from classmates, friends, or instructors) complete the patient analysis form on Canvas under "Lab Materials – Lab 7 – Patient Analysis Independent."
- COPY AND PASTE THE SUMMARY PARAGRAPH IN THE CORRECT DISCUSSION BOARD ON CANVAS FOR EACH WEEK.
- You will have 48 hours after your lab section to complete the form and submit the summary paragraph to the discussion board on Canvas.
- You will receive (in lab) a designated author each week. You will use the "Peer Review Rubric" to provide a score for several categories (accuracy, clarity, etc.) which will add up to a final overall score.
- In addition to the scoring, you will provide written feedback in each of the rubric categories (e.g., you may remind them that the anatomical term for 'arm' is 'brachium.') You will not make any direct edits to their summary paragraph.
- You will have 2 days to complete the review and submit your feedback on Canvas as a reply to your author's post.
- You will receive feedback on your patient analysis, and make necessary revisions and submit those to Canvas on the Discussion Board for that week.
- You will have 2 days to make your revisions and submit them to Canvas.

STUDY II – Patient Analysis Form for the Intervention

Patient Analysis Form

UNIQUE LAB #:
GROUP #:
GROUP MEMBERS:

To submit this form, save it to your computer under the Patient ID name. Go to your specific lab section, and click on the "Assignments" tab on the left side of the screen, and upload the form to the specific UPPER BODY 1, UPPER BODY 2, LOWER BODY 1, LOWER BODY 2 submission field. You only need to submit 1 form per patient for each group.

1. Initial data collection

A. Patient ID -

B. Patient Injury – (explain how you know)

2. Interpretations & Expectations

C. Based on the patient's injury, where will their pain be localized?

D. Based on the patient's injury, how are the soft tissues affected?

E. Based on the patient's injury, what are the likely functional outcomes?

F. Explain why you expect these functional outcomes (what evidence?).

3. Communication of Results and Discussion

STUDY II – Peer Review Scoring Rubric for the Intervention

PEER REVIEW SCORING RUBRIC

Directions:
Select the number in the left column that best describes the level of the right column that the author achieved. After providing a score for each category, add the highlighted numbers for an overall score. Then, in the boxes below, provide specific feedback (not just "good job") for each category. If the author was incorrect or incomplete in their analysis, provide the correct or complete information for them. You will copy/paste this as a reply to the 1st draft paragraph of your designated author.

YOUR SCORE WILL NOT IMPACT THE GRADE THE AUTHOR RECEIVES, SO BE HONEST AND THOROUGH IN YOUR EVALUATION.

Score Range 0 = absent, 1 = some, 2 = half, 3 = most, 4 = all	**Category**
0 1 2 3 4	Complete use of terminology (Author included all relevant anatomical terms)
0 1 2 3 4	Accurate use of terminology (Author used terms correctly)
0 1 2 3 4	Complete identification of injured structures (Author included all damaged structures)
0 1 2 3 4	Reasonable implications for soft tissue (Author connected damage to relevant soft tissue)
0 1 2 3 4	Evidence to support expected outcomes (Author gave evidence for each outcome)
0 1 2 3 4	Overall clarity (Author wrote clearly and concisely)

OVERALL SCORE: ____________ (Add the circled numbers in the left column)

Feedback for complete use of terminology:
Feedback for accurate use of terminology:
Feedback for complete identification of injured structures:

<u>Feedback for reasonable implications for soft tissue:</u>
<u>Feedback for evidence to support expected outcomes:</u>
<u>Feedback for overall clarity:</u>

Assessments

STUDY II – PRE-Test

NAME: ______________________
UT EID: _______________________
Lab Unique #: _______________________

KIN 424: Applied Human Anatomy
Fall 2016
Lab Practical 1

Part A: Identification - Identify the labeled structures and / or answer the associated questions. Answer only in the space provided, keep answers short and concise, and be as specific as possible. (Total 60 pts)

1. Fill in the chart below for each of the labeled organs. Name the organ, fill in the abdominopelvic region (include right or left) it would predominantly be found in and name the organ system it belongs to. If it is not located in an abdominopelvic region put NA.

Organ	**Abdominopelvic region**	**Organ System**
A.		
B.		
C.		
D.		
E.		

2.
F. What is this proper anatomical name for the area of this long bone that falls between the tape?
____

G. What kind of tissue covers both ends of this long bone (be specific – 4 terms)?
____

3.
H. This bone is a part of which division of the skeletal system. ____________________
I. How would this bone be classified? ____________________

4.
This is the carpometacarpal joint for digit 1.
J. What type of synovial joint is this? ____________________
K. Circle the correct number of planes for this joint. Nonaxial / uniaxial / biaxial / multiaxial

5.
This is metacarpophalangeal joint.

L. What is the common name for this joint? ____________________

M. Structurally, what type of joint is this (be specific – 2 terms)? ____________________

6.

N. Structurally, what type of joint is this (be specific – 2 terms)? ____________________

O. Name the types of movement that are possible at this joint (2). ____________________

P. In what plane are the movements occurring? ____________________

7.

Q. Name this suture. ____________________

R. Structurally, what kind of joint is this? ____________________

S. Functionally, what kind of joint is this? ____________________

T. What kind of tissue is it composed of (be specific – 3 terms)? _________________________

8.

U. Name this structure____________________

V. This is an opening for what structure? ____________________

9.

W. Name this bony landmark. ____________________

X. What important gland does it protect? ____________________

Y. Name a structure (there are 2) that likely passes through the holes that you see. ____________________

10.

Z. Identify these bony landmarks. ____________________

AA. What bone do they articulate with? ____________________

BB. What is the name of this joint? _________________

11.

CC. Write the corresponding number for the cranial bone that contains a paranasal cavity. ____________________

DD. Name the only facial bone that has a similar cavity. ____________________

12.

EE. Name this facial bone. ____________________

FF. On which cranial bone are the superior and middle equivalents of this bone? ____________

13.

GG. Name this vertebrae (be specific). ____________________

HH. What is this structure? ____________________

14.
II. What kind of vertebrae is this? ____________________
JJ. What do these structures articulate with (be specific)? ____________________

15.
KK. What is a possible function for this structure? ____________________
LL. Name this structure. ____________________

16.
MM. What is the name of this *shallow* groove? ____________________
NN. Of the lobes it separates, which one contains the primary motor cortex? ____________________

OO. *Sutures* are to the bones of the skull as *Fissures / Gyri / Sulci* are to the lobes of the brain.

17.
PP. What is this structure of the diencephalon? ____________________
QQ. It is associated with which ventricle? ____________________

18.
RR. This area of the cerebrum is made up primarily of white / gray matter and consists mostly of neuronal cell bodies / axons.
SS. Name this region of the brain stem. __________________
TT. The region above is made up primarily of white / gray matter and consists mostly of neuronal cell bodies / axons.

19.
UU. Which cranial nerve is this (provide name or number)? ____________________
VV. This cranial nerve is purely sensory / motor.

20.
WW. Which cranial nerve is this (provide name or number)? ____________________
XX. This cranial nerve is primarily motor and is responsible for the movement of what (along with 2 other cranial nerves)? ____

Part B: Histology - Identify the labeled structures and / or answer the associated questions on the PowerPoint. Be specific when answering (25 pts)

Slide 1:
24. What kind of epithelium is this? ____
25. What is its function? ____

Slide 2:
This is a tissue section taken from the small intestine.
26. What kind of epithelium is the arrow pointing to? ____________________
27. What would be a possible function for this epithelial layer? ____________________
Slide 3:
This is a tissue section from thick skin.
28. What kind of epithelium is the arrow pointing to? ____________________
29. What kind of surface modification does it have? ____________________
30. What would be a possible function for this epithelium? ____________________

Slide 4:
31. What kind of connective tissue is occupying most of this slide (be specific – 3 terms)? ____________________
32. What would be a possible function for this tissue? ____________________

Slide 5:
33. What kind of tissue is this (be specific – 3 terms)? ____________________
34. Provide one location where you would find this kind of tissue in the body. _______________

Slide 6:
35. What kind of tissue is this (be specific – 2 terms)? ____________________

Slide 7:
36. What kind of tissue is this (be specific – 3 terms)? ____________________
37. If the term 'costal' is used to describe the location of this tissue in the body, where is it? ____

Slide 8:
This is a longitudinal section of a nerve.
38. What is the equivalent structure called in the central nervous system? ___________________
39. Fascicles are composed of bundles of what structures? ____________________
40. What is this connective tissue covering called? ____________________

Slide 9:
41. Structurally, what kind of neuron is this? ____________________
42. This neuron carries impulses <u>away from / towards</u> the CNS.
43. Generally, these nuclei are from what kind of cells? ____________________

Slide 10:
This is a tissue section taken from the dorsal root ganglion.
44. What is the equivalent structure to a 'ganglia' called in the central nervous system? _______

45. Structurally, what kind of neurons are these? ____________________
46. Specifically, these are nuclei from which 'supportive' cells? ____________________

Slide 11:
This is a cross section of the spinal cord.
47. This is the ventral side so it is composed primarily of motor / sensory neurons.
48. Of the 3 functional groups of neurons, which ones are contained completely within the spinal cord? ____________________

Part C: Multiple Choice - Circle the most appropriate answer. (15 points)
3. Which region is visible only on the posterior/dorsal body surface?
A) buccal
B) calcaneal
C) mammary
D) patellar
4. A patient has a bruise on the ventral surface of the upper limb just distal to the antecubital region. It is located on the ________.
A) anterior arm
B) anterior forearm
C) posterior arm
D) posterior forearm

5. Which of the cartilage types below is matched correctly to it body location?
A) hyaline; between bodies of vertebrae
B) elastic; at the ends of the bones where they form joints
C) fibrocartilage; meniscus of the knee

6. Pronation and supination are movements of the ________.
A) elbow
B) head
C) palm of the hand
D) shoulder

7. This bone does *not* articulate with any other bone in the body. Muscles of the neck and tongue attach to it.
A) hyoid
B) mandible
C) occipital

D) palatine

8. Which of the following best describes the orbicularis oris?
A) It closes, purses, and protrudes the lips.
B) It pulls the lower lip down and back.
C) It draws the eyebrows together.
D) It closes the eye.

9. Which muscle(s) is (are) contracted to exhale forcibly?
A) diaphragm alone
B) internal intercostals and rectus abdominus
C) external intercostals and diaphragm
D) rectus abdominis and diaphragm

10. The ________ is the prime mover of jaw closure.
A) hyoglossus
B) masseter
C) lateral pterygoid
D) buccinators

11. This muscle closes the eyes, allowing you to wink or blink.
A) orbicularis oris
B) orbicularis oculi
C) frontal belly of the epicranius
D) corrugator supercilii

12. Cerebrospinal fluid formed in the lateral ventricles travels through the ________ to reach the third ventricle.
A) interventricular foramen
B) cerebral aqueduct
C) median aperture
D) central canal

13. In which lobe of the brain is the primary visual cortex located?
A) frontal
B) parietal
C) temporal
D) occipital

14. This muscle is named for the direction of its fibers.
A) external oblique
B) gluteus maximus
C) sartorius
D) tibialis anterior

15. A muscle located on the anterior surface of the thigh will ________ the knee, whereas a muscle on the posterior surface will ________ the knee.
A) flex, extend
B) extend, flex
C) abduct, adduct
D) adduct, abduct

16. This muscle compresses the cheek when you whistle.
A) levator labii superioris
B) buccinator
C) masseter
D) depressor labii inferioris

17. An agonist for elbow flexion is ________, whereas the ________ is an antagonist to this movement.
A) triceps brachii, brachialis
B) brachioradialis, deltoid
C) deltoid, biceps brachii
D) biceps brachii, triceps brachii

Part D: Clinical Questions (Extra Credit) These clinical questions will examine your ability to apply the information that you have learned in lab. Please read the questions carefully and answer them fully. Write your answer in the space provided; answers outside of the designated space will not be graded. A score of 1 – 5 on this section will give you **1 point** added to your lab practical and a score of 6 – 10 will give you **2 points**.

1. Over time, smokers develop a persistent cough known as "smoker's cough." Considering cigarettes' damaging effect on the lining of the respiratory track, explain this cough. (2.5 points)

2. Kanye West arrives at the emergency room following a neck injury which occurred while trying to lift his big head. X-rays indicate that the injury caused crush fracturing to the left most lateral structures of the 4th, 5th, and 6th cervical vertebrae. However, scans also found no dislocations of the vertebrae, and no bone fragments in the intervertebral spaces. Explain why this could be a very serious condition. (2.5 points).

3. Janet is a 57 year-old female who enjoys walking and tennis to remain physically fit. After seeing her doctor for some shoulder pain, her X-ray scans show that she has bone-on-bone contact between her humerus and scapula. Janet's doctor says that it is not surprising to have this condition, as the shoulder is the most susceptible of the upper body joints. First, what normally prevents bones from making direct contact with each other? Secondly, why is the shoulder the most likely to have this problem? (2.5 points)

4. While "acting" in a scene for her next terrible movie, Kristen Stewart trips over a prop and hits her head on a table. Upon arriving at the emergency room, she complains of blurry vision and appears very unstable when she walks. What underlying neurological structures may be injured, and based on this information, what part of her head did she hit? (2.5)

STUDY II – POST-Test

NAME: ________________________
UT EID: ________________________
Lab Day / Time: ________________________

KIN 424: Applied Human Anatomy
Spring 2017
Lab Practical 2

Part A: Identification - Identify the labeled structures and / or answer the associated questions. Answer only in the space provided, keep answers short and concise, and be as specific as possible. (65 pts)

1.
A. What is this structure? ___________________________
It forms a 'lid' over what structure during swallowing? ___________________________

2.
B. This structure marks the beginning of the upper / lower respiratory tract.
Compared to the terminal bronchioles, this structure has more / less smooth muscle in its walls.

3.
C. Name these cord-like structures. ___________________________
These work with what muscular structures to prevent backflow of blood into the atria?
____

4.
D. These vessels supply blood to what tissue (be specific)? ___________________________
Deoxygenated blood from these vessels collects into the great cardiac vein and gets returned to which chamber of the heart? ___________________________

5.
List the vessels a drop of blood passes through as it goes from the left ventricle to the tip of left digit V (there are six).

6.
Right / Left (circle correct one)
E. Name a muscle that originates here (there are 2). _________________________________
Name an action for the muscle you listed above. _________________________________
F. Another bone articulates here to form what joint? ________________________________

7.

The muscles responsible for *returning this hand to anatomical position* are in the anterior / posterior compartment of the ___________________________.
Where do most of these muscles originate (bony and bony landmark)?
____
Circle the muscle below that could be responsible for returning the hand to anatomical position.
Extensor carpi radialis longus / Extensor pollicis brevis / Flexor carpi radialis

8.
G. This fossa accommodates the (bony landmark?) _______________ of the (bone?) _______________ to form part of the elbow joint.
H.What bone articulates here? ___________________________

9.
I. Name one of the actions of this muscle.
____
Where does it insert (bone and bony landmark)?
____
J. Name this muscle. ____
Name one movement performed by this muscle.
____

10.
Name the muscle labeled A. ___________________________
What is its 'individual' action? ___________________________
Name the muscle labeled D? ___________________________
Where does it originate? __________________________________

11.
K. Bone of origin: ___________________________
Bone of insertion: ___________________________
Action: ___________________________

12.
L. This joint is formed by the radius articulating with which 2 carpal bones? ___________ & ____________
M. Name this bone (be specific). ___________________________

13.
Name the muscle labeled C (be specific). ___________________________
Where does this muscle insert (bone and bony landmark)? ___________________________
What is the action of muscle E? ___________________________
Which of the labeled muscles is involved in forearm flexion? _____

14.
Right / Left (circle correct one)
N. Name this structure; provide the scientific name and the common name.
____
O. Which group of muscles inserts here? ____________________________
Collectively, what is their primary action? ____________________________

15.
List the letters for the muscles that are involved in abduction of the thigh. _____
Where do they insert (bone and bony landmark)? __________________________
List the letters for the muscles that are involved in flexion of the thigh _____
Where do they insert (bone and bony landmark)? __________________________
Of the labeled muscles, which is the most superficial? _____

16.
Of the 4 major muscles that occupy the anterior compartment of the thigh, which one are you unable to see on this model? __________________________
Which one also flexes the thigh? __________________________

17.
Is pelvis 'A' male or female? __________________________
Name the joint indicated by the arrows. __________________________
T / F: This joint can be used to tell the two pelves apart.

18.
P. Name this structure. __________________________
Which of the two inferior bones that you see is NOT weight bearing?
____
Q. Name this structure. __________________________
R. What kind of tissue is this (be specific – 3 terms)?
____

19.
Where do all 3 muscles that occupy the posterior compartment of the thigh originate (bone and bony landmark)? __________________________
Name one action that these muscles perform? __________________________
Which of these muscles is the most lateral? __________________________

20.
Name the muscle labeled C. __________________________
List the letter(s) for the muscle(s) that act on the feet or toes. _____

What muscle inserts on the structure labeled F, but is not pictured on the model?
____

21.
S. What is the primary action of this muscle? _________________________
Name a synergistic muscle. _________________________
T. Name this muscle. _________________________
Where does the muscle above originate (bone and bony landmark)?
____________________________ _________________________

Part B: Histology - Identify the labeled structures and / or answer the associated questions on the PowerPoint. Be specific when answering (15 pts)

Slide 1:

49. What type of tissue is this (be specific)? _________________________
50. How do you know? ____
51. List **one** possible structure (there are 2) that is accounting for this darker staining line. _________________

Slide 2:

52. This is cardiac muscle tissue (low magnification). What are the purple staining structures that you see (be specific)? _________________________

Slide 3:

53. This is a cross section of what structure of the respiratory tract? _________________________
54. What surface modification does it have? _________________________
55. This tissue forms C-shaped rings in this structure. Provide one reason why? ____

Slide 4:

56. From what organ is this tissue section taken? _________________________
57. What is most of the tissue that you can see? _________________________
58. Specifically, which respiratory process (of the 4) is this tissue involved in? _________________________

Slide 5:

59. What kind of vessel is this (be specific)? _________________________
60. What kind of tissue is this layer primarily composed of? _________________________

Slide 6:
The black structures that you see are elastic fibers.
61. What kind of structure is this (be specific)? ________________________
62. This tissue section is taken from a structure that is close to / far away from the heart.
63. Which layer is this? ________________________

Part C: Multiple Choice - Circle the most appropriate answer. (20 points)

1. These vessels carry oxygen-rich blood.
A) aorta and pulmonary trunk
B) venae cavae and pulmonary veins
C) aorta and pulmonary veins
D) venae cavae and pulmonary artery

2. What is *true* about heart valves?
A) They enforce a one-way blood flow through the heart.
B) They operate passively (no active contraction required).
C) They separate atria from ventricles, and ventricles from the large arteries that leave them.
D) All the above

3. Blood arriving in the right atrium has just come from the ________.
A) venae cavae and coronary sinus
B) venae cavae
C) right ventricle
D) left atrium

4. The bicuspid (mitral) valve is located between the ________.
A) right atrium and right ventricle
B) right ventricle and aorta
C) left ventricle and pulmonary trunk
D) left atrium and left ventricle

5. The heart is located in a subdivision of the thorax called the ________.
A) dorsal cavity
B) mediastinum
C) pleural cavity
D) epigastric cavity

6. The subclavian artery that arises directly from the aorta supplies the ________.
A) right upper extremity and neck
B) left upper extremity and neck
C) anterior trunk wall
D) posterior trunk wall

7. The aorta terminates when it divides into the ________.
A) common carotid arteries
B) common iliac arteries
C) great saphenous arteries
D) femoral arteries

8. This tunic is much thicker in a muscular artery than in its corresponding vein.
A) tunica intima
B) tunica media
C) tunica externa

9. The ________ artery carries blood from the subclavian to the brachial artery.
A) radial
B) ulnar
C) axillary
D) brachiocephalic

10. Which of the following muscle does *not* form part of the rotator cuff?
A) teres minor
B) supraspinatus
C) infraspinatus
D) teres major

11. Extension of the elbow stops when the proximal end of the ulna engages the ________.
A) coronoid fossa of the humerus
B) medial epicondyle of the humerus
C) olecranon fossa of the humerus
D) trochlea of the humerus

12. The thick and thin filaments of muscle are made up of ________, respectively.
A) myosin and actin
B) the dark and light bands
C) the H zone and the Z disc
D) T tubules and terminal cisterns

13. This powerful muscle is the prime mover of arm extension.
A) latissimus dorsi
B) triceps brachii
C) supraspinatus
D) teres minor

14. The range of motion at the shoulder is greater than the range of motion at the hip because
A) the humerus is held tightly to the glenoid fossa
B) the pectoral girdle forms a complete circle and is firmly attached to the axial skeleton
C) very strong ligaments wrap around the humerus in all directions to hold it to the pectoral girdle
D) the glenoid fossa is a very shallow cavity

15. A muscle located on the anterior surface of the thigh will ________ the knee, whereas a muscle on the posterior surface will ________ the knee.
A) flex, extend
B) extend, flex
C) abduct, adduct
D) adduct, abduct

16. Body weight is borne by the two largest tarsal bones: ________ and ________.
A) talus, navicular
B) navicular, cuneiform
C) navicular, calcaneus
D) talus, calcaneus

17. This part of the hip bone bears your weight when you sit (‘sits’ bone).
A) iliac fossa
B) inferior ramus of the pubis
C) ischial ramus
D) ischial tuberosity

18. The primary action of muscle on the medial compartment of the thigh is ________.
A) flexion of the thigh
B) adduction of the thigh
C) extension of the thigh
D) abduction of the thigh

19. A superficial muscle of the leg, this one dorsiflexes the foot.
A) fibularis longus
B) gastrocnemius
C) soleus
D) tibialis anterior

20. Both the knee and the temporomandibular joints ________.
A) are modified hinge joints
B) perform protraction and retraction
C) perform only flexion and extension
D) bear the weight of the body

NAME: ________________________
Lab Day / Time: ________________________

Part D: Clinical Questions (Extra Credit) These clinical questions will examine your ability to apply the information that you have learned in lab. Please read the questions carefully and answer them fully. Write your answer in the space provided**; answers outside of the designated space will not be graded**. A score of 1 – 5 on this section will give you **1 point** added to your lab practical and a score of 6 – 10 will give you **2 points**.

1. A patient with pulmonary hypertension (high blood pressure) will experience a greater strain on their heart that will ultimately lead to cardiac failure. Describe, specifically, where the blood pressure is high, and explain how the heart's structure is not well-equipped to overcome this particular pressure. (1 point)

2. Margaret is a 59-year-old female patient admitted to the E.R. after unexpectedly losing consciousness while completing a dare from her friend Ethel, who said that Margaret could not still deadlift 600 pounds at her age. Electrocardiogram tests showed no electrical abnormalities in the heart. Angiogram (vessel scan) studies showed no blockages around the heart or in the blood vessels leading to the brain. Heart rate and blood pressure were normal. Given all these data, explain how a component of the heart might be contributing to Margaret's loss of consciousness. (1 point)

3. Jonah Hill is visiting his cardiologist following a minor heart attack. Jonah's cardiologist tells him that his excessive weight and poor diet have contributed to blockages in the blood vessels providing functional flow to his heart. Fortunately, angiogram studies have shown only one blockage in a vessel near the apex of the heart. Jonah's doctor tells him that if the blockage had occurred elsewhere in these vessels, his heart attack could have been much worse. Explain how the location of a blockage in these vessels can result in differing severities of heart attacks. (1 point)

4. During the NBA finals in 2014, the air conditioning stopped working at the Spurs' arena, leading to warm temperatures. Due to the temperature, the mighty Lebron James lost a lot of fluid (and the game) and had to exit early. After the game, James reported muscle spasms (cramps) running up the left side of his leg from his ankle to his hip. First, briefly explain why his description of where the pain is located might confuse the physicians trying to determine what muscles are cramping. Second, assuming that Lebron meant to say that his lateral left leg muscles were cramping, what movements would you predict will cause him pain? (1.5 points)

5. Two patients arrive at the E.R. following an injury sustained during a collision playing soccer. X-rays show Patient A to have only a hairline (minor) fracture of the tibia, while Patient B has a hairline fracture of the fibula. Patient B is able to walk out of the hospital, while Patient A requires crutches. Explain how these patients suffered a similar fracture, but have different outcomes (be very specific regarding how you know why their outcomes were different). (1 point)

6. Tom Brady arrived at the E.R. last night whining about knee pain after tripping over an under-inflated football in the locker room. Physical examination shows that he is sensitive to manual pressure between the medial femoral and medial tibial condyles. X-rays showed no bone fractures. Based only on the location of his pain, what structures might be damaged? There is too much swelling in the knee to get a clear MRI, but what additional structure can we hypothesize to also be damaged? How can we test this hypothesis? (1.5 points)

7. Athletes from volleyball, baseball, and tennis who use large amounts of “overhead” movements tend to suffer more shoulder injuries during their career. This is especially true of athletes who tend to medially rotate their arm while it is fully abducted. As they perform this movement over time, their humeral head starts to shift anteriorly due to muscle fatigue. This shift allows bones in the shoulder to “grind” during medial rotation of the abducted arm. First, explain how muscle fatigue can allow the humerus to shift anteriorly. Second, provide the muscle that can get trapped and damaged, as well as the bony landmarks that are “grinding” while medially rotating an abducted arm. (1 point)

8. While Shakira’s hips may not lie, they also do not last. Her doctor has recommended hip replacement surgery. During hip replacement surgery, both the “ball” and “socket” components of the joint are replaced with titanium, and connective tissue structures associated with the “ball” and “socket” are removed. The amount of physical therapy needed after the surgery is extensive due to the joint’s instability and the ease with which it can dislocate itself. First, list the structures being replaced and the structures being removed, and then explain how the removed structures can lead to a less stable hip joint. Second, explain how physical therapy exercises attempt to compensate for the lost structures. (1 point)

9. Emergency Medical Services arrive to the scene of an accident where it appears that a man on a bike struck Miley Cyrus like a wrecking ball while she was walking down the street. X-rays at the hospital show that she suffered fractures to both her distal radius and distal ulna. Miley reports that the injury occurred when she put her hand out in front to stop the cyclist. First, explain why fracturing both the radius and ulna in this situation is abnormal. Second, describe (in anatomical terms) how the impact must have moved her hand to achieve these fractures. (1 point)

ADI – IRB Proposal

1. Title

   Another Way to Skin a Cat: Applying Argument-Driven Inquiry to the Undergraduate Anatomy Laboratory

2. Principal Investigator

   Philip Cheshire, pac2323, Kinesiology & Health Education

3. Purpose

   In the U.S., there is a growing need for healthcare professionals in many fields. According to the U.S. Bureau of Labor Statistics, healthcare occupations and industries are expected to have the fastest employment growth and to add the most jobs between 2014 and 2024 (BLS.gov). Of the undergraduate prerequisites for almost all healthcare professional schools, human anatomy is among the most challenging due to its volume and integrated use of applied analysis. Very few undergraduate programs in the U.S. allow for the full exploratory process of human cadaver dissection (Collins et al., 1994); relying on the use of anatomical models and virtual media. Even medical school anatomy programs incorporate greater dependence on alternative pedagogical systems such as problem-based learning (Azer & Eizenberg, 2007), peer teaching (Krych et al., 2008), and web-based teaching materials (Bryner et al., 2008; Petersson et al., 2009). While these learning systems appear to be advances in anatomical education, Winkelmann's 2007 review of novel teaching methods found that they failed to drive better learning outcomes and deemed them "not disadvantageous." Additionally, the current literature's focus on medical school-level anatomy ignores the vast majority of students taking this course: undergraduates; a more varied population in academic background and ability than medical students. Reaching undergraduates may require a more integrated approach as it appears to be an effective means to help a larger number and greater diversity of students (NRC, 2005). Ultimately, in the absence of a full anatomical education experience, there is a continued need for the development of instructional processes that allow for a greater overall development of future scientist-practitioners. This study proposes the application of a novel integrative instructional system to the anatomy laboratory that will assist in the development and retention of future healthcare practitioners.

A novel pedagogical system not included in Winkelmann's review is Argument-Driven Inquiry (ADI). Proposed by Sampson & Gleim in 2009, ADI is an instructive approach that helps students develop the ability to bring in information, organize it, retain it, and ultimately apply it (Sampson & Gleim, 2009). ADI also provides students with a way to develop crucial mental habits and critical thinking skills through emphasizing argumentation's role in creating and making sense of scientific knowledge (Driver, Netwon & Osborne, 2000; Duschl & Osborne, 2002). This methodology focuses on constructing an argument (similar to a legal argument) founded on known evidence to generate a well-reasoned answer to a question (much like healthcare professionals diagnose unknown health problems from a set

of known symptoms). ADI, uses data collection and analysis, peer-to-peer conversational learning, and scientific writing to allow students to explore, organize, communicate, and preserve their content knowledge as well as their understanding of the discipline's specific scientific practices (Sampson, 2009). According to the National Research Council, when compared to standard laboratory activities, this integrated approach to science education demonstrates a greater ability to enhance mastery of subject area, develop scientific reasoning, and cultivate an interest in science (NRC, 2005, 2007).
This study will incorporate the ADI methodology in the upper division Kinesiology course 'Applied Human Anatomy.' Through the use of case-studies, students will use ADI processes to collect content information (data), which will allow them to develop an argument describing potential anatomical roots for the fictional patients' maladies. We will be evaluating the application of ADI to the anatomical laboratory by measuring learning outcomes, student self-efficacy towards anatomy, and intention to pursue healthcare-related career tracks. We will then compare these outcomes to the standard method of instruction.

4. Procedures

The course will be separated into a Control and ADI semester over the course of 1 year to avoid contamination between conditions. The course instructors will be blinded as to who has or has not consented to participate. Lab sections in the control condition will use the course's standard worksheet-based learning methodology. Lab sections in the ADI condition will use a case study-based methodology. All students will have access to the same pre-lab review materials, as well as external opportunities to engage with laboratory instructors.

The ADI participants will have access to an online link through the University web-based class management system: Canvas. The link will take the participants to a case-study relevant to the week's topic (e.g., bones and muscles of the shoulder). The participants will be given medical information on an imaginary patient, and then will be guided through a series of prompts. Participants will be asked to 1) collect data from medical scans and forms, 2) develop hypotheses regarding potentially damaged structures, 3) predict functional outcomes for the patient, and 4) write a patient summary using scientific and anatomical language. After forming a written patient summary, students will engage in a randomized, double-blind peer editing process. Following the reviews, participants will have the opportunity to revise their work.

Demographic questionnaires will be accessible to participants through an online link to the UT Survey tool, Qualtrics, sent via email to students. Only the un-blinded member of the research team will have access to the information gathered through this survey.

a. Location

The University of Texas at Austin. Belmont Hall.

b. Resources

No internal/external funds will be used for this study.

c. Study Timeline

Data collection will begin in the fall semester of 2016, and continue through the spring semester of 2017. The results and manuscript will be produced during the summer of 2017.

5. Measures

Outcome measures are in academic performance. Therefore, the standard lecture exam scores, standard lab exam scores, and standard post-lab quiz scores will be used to measure general content knowledge. Additionally, separate “clinical application” questions will be collected halfway through the semester as well as at the end of the semester in order to assess scientific reasoning skills. These clinical assessment questions will have no potential for negative impact on the students, and will serve as an extra credit opportunity for all students. The questions can be found in the additional documents section of the proposal. Finally, participants will receive a questionnaire asking them to provide demographic information (age, sex, race, and if they have previously been enrolled in the course). The questionnaire also includes items regarding perceptions of professional readiness and intentions to pursue healthcare-related professions.

6. Participants

a. Target Population

College-age students enrolled in an undergraduate human anatomy course. The sample size is anticipated to be 200 students.

b. Inclusion/Exclusion

Any student enrolled in the course may be included in the analyses. Exclusion criteria are (1) the participant is retaking the course, and/or (2) the participant does not complete the course.

c. Benefits

Participants in this study may experience a more valuable and engaging learning environment. Additionally, participants may experience a benefit to their academic performance.

d. Risks

There are no anticipated risks for participants in this study.

e. Recruitment

Students from the fall 2016 and spring 2017 semesters will be recruited in-person by a member of the research team that does not have access to course grades during normal course hours’ time.

f. Obtaining Informed Consent

Students from the fall 2016 and spring 2017 will receive the written informed consent. Participants will be asked to sign a written informed consent form. The consent form will be reviewed by the recruiting member of the research team with the potential participants.

7. Privacy and Confidentiality

All electronic information related to participant identity will be coded for de-identification, and then deleted and written over. Additionally, all hard-copy materials will be maintained in a locked cabinet in Belmont 849. Only authorized research personnel have access to this area.

Confidentiality of the Data or Samples

All data will be stored on a password-protected computer. Confidentiality of the data will include the following steps:

(1) collect the hard copies of the assessments from the instructor once the end of semester grades have been submitted. Any identifying information on the hard copies will be immediately be redacted (permanent marker) and replaced with a unique identifier code (alphanumeric).

(2) collect the electronic records of academic outcomes following the completion of the semester.

The participant data will be de-identified when transferred to the password-protected computer. All identity-related materials on the computer will be deleted and written over.

(3) de-identify all participants by assigning alphanumeric codes to individuals

There will be no master/key file for participant identities. Data collection will occur at one time, so individual participant identities will not need to be maintained. All hard copies of assessments (mid-term and final exam clinicals) will be transcribed according to numerical code. These procedures will allow the assessments to be returned to the course instructors for the maintenance of their records.

All de-identified data will be maintained indefinitely. Hard copy forms will be maintained for a period of 5 years, after which, hard copies will be shredded. These data will not be shared outside of this study.

8. Compensation

Participants will receive no compensation for participation.

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IRB USE ONLY
Study Number:
Approval Date:
Expires:

Consent for Participation in Research

Title: Applying argument-driven inquiry to the undergraduate anatomy laboratory.

Introduction

The purpose of this form is to provide you information that may affect your decision as to whether or not to participate in this research study. The person performing the research will answer any of your questions. Read the information below and ask any questions you might have before deciding whether or not to take part. If you decide to be involved in this study, this form will be used to record your consent.

Purpose of the Study

You have been asked to participate in a research study about anatomy education at the undergraduate level. The purpose of this study is to examine how a learning system based on argumentation compares to the standard laboratory experience.

What will you be asked to do?

If you agree to participate in this study, you will be asked to

- Provide your age, race, sex, and whether you have enrolled in this class before
- Allow your academic assessments to be used in data analysis
    - These assessments are FERPA protected, and will remain confidential

This study will take **20 minutes** and will include approximately **200** study participants.

What are the risks involved in this study?

There are no foreseeable risks to participating in this study.

What are the possible benefits of this study?

The possible benefits of participation may include improved academic performance.

Do you have to participate?

No, your participation is voluntary. You may decide not to participate at all or, if you start the study, you may withdraw at any time. Withdrawal or refusing to participate will not affect your relationship with The University of Texas at Austin (University) in anyway.

If you would like to participate please sign this form, and return it to the research personnel reviewing it with you. You will receive a copy of this form.

Will there be any compensation?

You will not receive any type of payment participating in this study.

How will your privacy and confidentiality be protected if you participate in this research study?

Your privacy and the confidentiality of your data will be protected by (1) academic outcomes will be downloaded to a USB drive collected from the instructor and de-identified when transferred to the password-protected computer. (2) All study-related materials on the USB drive will be deleted. All data will be maintained for 5 years, after which, hard copies will be shredded. These data will not be shared outside of this study.

If it becomes necessary for the Institutional Review Board to review the study records, information that can be linked to you will be protected to the extent permitted by law. Your research records will not be released without your consent unless required by law or a court order. The data resulting from your participation may be made available to other researchers in the future for research purposes not detailed within this consent form. In these cases, the data will contain no identifying information that could associate it with you, or with your participation in any study.

Whom to contact with questions about the study?

Prior, during or after your participation you can contact the researcher **Andy Cheshire** at **andyc6@utexas.edu** for any questions or if you feel that you have been harmed.
This study has been reviewed and approved by The University Institutional Review Board and the study number is **2016-01-0014.**

Whom to contact with questions concerning your rights as a research participant?

For questions about your rights or any dissatisfaction with any part of this study, you can contact, anonymously if you wish, the Institutional Review Board by phone at (512) 471-8871 or email at orsc@uts.cc.utexas.edu.

Participation

If you agree to participate please return this form to the research personnel reviewing it with you.

Signature

You have been informed about this study's purpose, procedures, possible benefits and risks, and you have received a copy of this form. You have been given the opportunity to ask questions before you sign, and you have been told that you can ask other questions at any time. You voluntarily agree to participate in this study. By signing this form, you are not waiving any of your legal rights.

____

Printed Name

________________________________ ________________

Signature Date

As a representative of this study, I have explained the purpose, procedures, benefits, and the risks involved in this research study.

____

Print Name of Person obtaining consent

________________________________ ________________

Signature of Person obtaining consent Date

ADI - Recruitment Script

Hello,

You are invited to participate in a study being conducted to learn more about anatomy education at the undergraduate level. The study will take place in the lab sections, and will be comparing a clinically-based system of scientific argumentation to the course's standard procedures. We are asking for your participation in the study, which will allow the research team to use your academic outcomes on exams and assessment for data analysis.

Participation is completely voluntary, and there is no penalty for not participating. Everyone in the lab will be engaging in the new procedures, however, you can choose not to consent for your data to be included in the analysis.

All of the information provided will be confidential, and will be de-identified. Specifically, your academic data is FERPA protected, and will not be shared outside of the study. Your instructors will not know who is and who is not participating. If you have any questions regarding the study, you are welcome to contact the Principal Investigator, Andy Cheshire via email at andyc6@utexas.edu.

Thank you!

STUDY III MATERIALS

STUDY III – P HYSICIAN CHEAT SHEET

Introduction	Published risks for Central Lines (IJs) in hands of experienced providers
Get to Know Each other: Who are you? What do you do for a living? What do you do for fun? Where have you all gone to school?	Pain Unknown
Normalize Experience and Variation in Practice	Arrhythmias 41% (usually atrial, can be PVCs/Vtach) Nurse says, "Pull back" S/he means "VTach)
How do you set up your kit?/What are the components of the kit?	Infection 16%
What was hardest part of learning procedure?	Arterial Puncture 5%
What practice variation have you seen?	Pneumothorax 1%
Practice Psychomotor Skills- Repeat with 2-3 students	Venous Air Embolus 0.2-1%
Reiterate Patient should be in Trendeleburg to increase vein size and reduce risk of air embolus	Stroke 0.1%
Now draw a carotid/IJ on anatomy sponge for either right or left side Place this "over" the cadaver, and walk through the steps	Central Line Placement in Cadaver (Right side is tied off by mortician, use left whenever possible)
Place needle into vessel, pulling back on syringe while advancing needle Have students practice, they struggle with this). Bevel down has lowest risk of hematoma formation	Review what anatomy is visible in cadaver on right and left, with skin down and up. See what vessels are tied off (mortician ties some off) Demonstrate differences in distance to RA from right/left position
Place wire through the syringe, or disconnect syringe (cover with thumb to avoid air embolus)---This is where we would add transducing tubing	Review Surface Anatomy- including sternocleidomastoid heads/clavicle, staying 3 fingers above the clavicle
Place wire to 15cm if syringe removed/ 25 cm if through syringe Make a nick in the sponge	Use the FINDER needle- at top of triangle pointing towards ipsilateral nipple (i.e. away from the carotid
Dilate the vessel (do not hub the dilator) Place the catheter over the wire (maintain control of wire)	When possible, pull back skin to see if needle is anywhere near the IJ
Place at 15-20 depending in height of patient, goal is the SVC/RA junction	Use large needle on top of finder needle to try to get into the vessel You may end up showing how often we

	missed" the IJ this old way
US tips	Wire will thread if you are in vessel, but may not go to intended depth and may exit the vein as it is friable
US tips in a LIVING PERSON	Remove the syringe –since wire will not go in that far, this demonstrates how important it is to hold onto the wire s
Review surface Anatomy- triangle of sternocleidomastoid and the clavicle Align transducer to screen	Dilate the vessel- show how superficial/deep you would have to go
Show vein versus artery with Compression/Doppler Show impact of Valsalva in vein size Show transverse/Longitudinal Views	Place line over wire- show how on the left side, you would have to go all the way to 20cm to reach SVC/RA junction

Flipped Classroom Concepts

Informed Consent	Infection Control
Patient must have capacity	Subclavian is the preferred site nationally, but may not be possible due to patient condition
Provide enough information that a reasonable person could consent for procedure (doesn't need to include every possible complication)	WASH YOUR HANDS
Provide risks, benefits and alternatives	Prep with chlorhexidine- in back and forth/up and down motion
The risks should be shared in language patients can understand (when possible do not use percentages, instead 1 in 10 people)	Full Barrier Precautions: All people in room should wear hat, mask-Proceduralist should also wear gown and gloves Use a full body drape for the patient
The conversation is more important than the actual document	Assess the line daily for removal
Informed consent should be repeated every time a new procedure is being done; sometimes use old if signed consent for same patient/same operator	Use US when possible- reductions in time to insertion reduce infectious risk
Informed consent not needed for emergent procedures- two physicians can sign for medical need	Handwashing reduces 30% of all infections
Informed consent should have a witness present	Central-line associated blood stream infection increases costs by about $50-60,000/patient and increases the odds of dying
Timeouts	**US and Other TIPS**
Correct Patient using double identifier (patient	Assure Correct transducer/patient alignment

name plus at least one other item, such as DOB and/or MRN	
Correct Procedure, confirm with signed consent form	Look for Compressibility of the vein/Doppler (can use transverse or longitudinal view)
Correct Site (look for markings by proceduralist)	Confirm Wire is in correct location before you dilate vessel, by looking in the transverse and longitudinal views
Correct Equipment is available	Policy in some parts of the hospital to use transducing tubing attached to the needle to confirm that the needle remains in the vein prior to dilation of the vessle
Review of patient data- allergies, labs, radiographs	Confirm anatomy prior to use of ultrasound to avoid going to close to the clavicle
Different Colored hats in the OR to identify where patient is in timeout process (red- not ready, blue- ready to go)	The fatter and shorter the line, the better for rapid infusion of fluids (Poiseuille's Law)
Team encouraged to speak up	MAC> 2 16G IVs> TLC> 2 smaller IVs > PICC for rapid/large volume
Documentation of timeout in procedure note	
Debrief of Procedure	

Assessments

STUDY III –
Factual Knowledge Pre- & Post-Assessment

Professional Practices & Medical Knowledge –

Which of the following statements regarding the processes of obtaining informed consent or performing a “time out” in patient care is **MOST ACCURATE**?

A. Informed consent should include all of the known risks of a procedure
B. The informed consent document is more important than the informed consent discussion
C. *Informed consent should be completed for every procedure, even if the procedure is a repeat procedure (for example, a patient requires a second central line placement)
D. When performing a timeout, the “double identifier” refers to two people from the team confirming that it is the correct patient
E. When performing a time out, it is essential that all of the correct family members of the patient are present.
F. When performing a time out, it is not necessary to confirm the patient identity, procedure, and site if all of this has already been done for the consent process.
G. When performing a time out, a review of patient allergies, labs, and relevant imaging findings is needed only for patients undergoing general anesthesia.

Which statement about hospital-acquired infections (HAI) is **MOST ACCURATE**?

A. CLABSI (central line-associated blood-stream infection) is the most common HAI.
B. *CLABSI increases patient costs and mortality.
C. HAI’s kill more than 98,000 people per year.
D. The single most important way to reduce HAI is to use full barrier precautions.
E. During surface preparation of the skin prior to a medical procedure, betadine solution is generally preferred over chlorhexidine.

Components of the central line bundle to prevent infection include ALL of the following **EXCEPT**:

A. Handwashing
B. *All individuals in the room must wear hat, mask, gowns and gloves
C. Full body drape of the patient
D. Chlorhexidine should be applied in back and forth and up and down
E. Placement in the subclavian vein is the preferred site over the internal jugular as there is generally less risk of infection.

Which of the following statements regarding venous central lines is **MOST ACCURATE**?

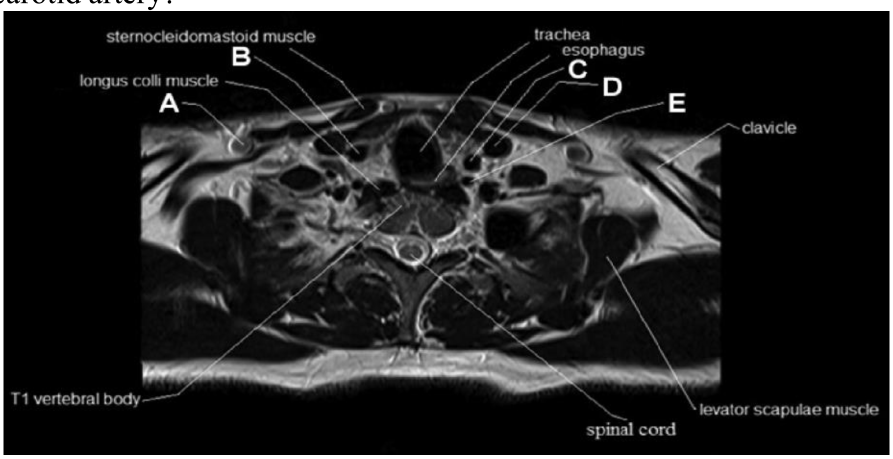
A. Triple Lumen Catheters are generally preferred over Multi-Access Catheters (MACs) for large volume resuscitation.
B. The risk of a pneumothorax is higher with an internal jugular (IJ) central line a subclavian line.
C. Femoral lines have a higher risk of infection in males compared to IJ lines.
D. *It is preferable to have the patient in the Trendelenberg position when placing a central line.
E. In patients with clotting deficiencies, a subclavian line is preferable as this is more a compressible site compared to an IJ line in case of mechanical complications.

Anatomical Knowledge –

Which of the following statements regarding the anatomy of the neck is **MOST ACCURATE**?

A. The external jugular vein is typically found within the carotid sheath in the anterior triangle of the neck just medial to the sternal head of the sternocleidomastoid.
B. *The internal jugular vein is typically positioned antero-laterally to the common carotid artery just lateral to the clavicular head of the sternocleidomastoid.
C. The vagus nerve is typically positioned outside of the carotid sheath in the posterior triangle of the neck.
D. The sternocleidomastoid muscle defines the medial boundary of the anterior triangle of the neck.
E. **ALL** of the above statements are accurate.

Which label in T1-weighted MRI of the lower neck provided indicates the LEFT common carotid artery?



A. A
B. B
C. *C
D. D
E. E

Q16 A patient presents to the emergency department following a motor vehicle crash. The patient was the driver of the vehicle and was wearing a seatbelt but suffered some injury nonetheless, including a laceration in the upper posterior triangle of the neck that resulted in loss of function of the LEFT sternocleidomastoid muscle. From the dropdown lists provided, select: the **nerve** that innervates this muscle and was likely damaged, and the **deficit** that would **MOST LIKELY** be observed due to loss of function.
Nerve affected (1)
Deficit observed (2)

▼ glossopharyngeal nerve (0) ... recurrent laryngeal nerve ~ difficulty speaking / hoarseness (29)

Q18 A 6-year-old child that was recently treated for streptococcal tonsilitis is brought in to the emergency department with difficulty breathing and pain in the chest, throat, and neck. Upon exam, the child is febrile with extensive inflammation of the tonsils and pharyngeal mucosa. Imaging studies reveal an abscess in the posterior mediastinum of the chest at the level of the 2nd thoracic vertebra and the child is started immediately on intravenous antibiotics and undergoes surgical management to drain the abscess. Cultures of the fluid drained from abscess show bacteria similar that which was initially found in the tonsils. The **MOST LIKELY** route by which the infection spread into the posterior mediastinum is:

○ In the fascial plane between the retropharyngeal space and prevertebral space (1)

○ Within the carotid sheath (2)

○ Within the superficial fascia of the neck (3)

○ Lymphatic drainage of the upper pharynx and esophagus (4)

○ Within the pretracheal space (5)

Q19 A mechanical complication occurs during placement of an internal jugular central venous line on the right side that results in damage to the vagus nerve. The **MOST LIKELY** deficit that would be observed in this instance is:

○ complete loss of parasympathetic tone to the GI tract up to the left colic flexure (1)

○ bradycardia (2)

○ difficulty breathing (3)

○ hoarseness (4)

○ decreased saliva production (5)

STUDY III – Pre-test Student Perceptions

Pre-Test

Perceptions of Learning & Professional Preparedness –
Please rate the degree to which you agree with the following statements.

The standard gross anatomy dissection labs are engaging for me as a learner.

0	1	2	3	4	5
I choose not to answer	I do not Agree	Somewhat Agree	Halfway Agree	Mostly Agree	Completely Agree

After the standard gross anatomy dissection labs, I feel more prepared for the clerkships next year.

0	1	2	3	4	5
I choose not to answer	I do not Agree	Somewhat Agree	Halfway Agree	Mostly Agree	Completely Agree

After the standard gross anatomy dissection labs, I feel connected to clinical faculty I may work with during the clerkships.

0	1	2	3	4	5
I choose not to answer	I do not Agree	Somewhat Agree	Halfway Agree	Mostly Agree	Completely Agree

The standard gross anatomy dissection labs help me connect gross anatomy with clinical practice.

0	1	2	3	4	5
I choose not to answer	I do not Agree	Somewhat Agree	Halfway Agree	Mostly Agree	Completely Agree

The standard gross anatomy dissection labs allow me to experience realistic clinical practices.

0	1	2	3	4	5
I choose not to answer	I do not Agree	Somewhat Agree	Halfway Agree	Mostly Agree	Completely Agree

During the standard gross anatomy dissection labs, I feel like I am learning how to be a doctor.

0	1	2	3	4	5
I choose not to answer	I do not Agree	Somewhat Agree	Halfway Agree	Mostly Agree	Completely Agree

STUDY III – Post-test Student Perceptions

Post-Test

<u>Perceptions of Learning & Professional Preparedness –</u>
Please rate the degree to which you agree with the following statements.

The central line lab was engaging for me as a learner.

0	1	2	3	4	5
I choose not to answer	I do not Agree	Somewhat Agree	Halfway Agree	Mostly Agree	Completely Agree

After the central line lab, I feel more prepared for the clerkships next year.

0	1	2	3	4	5
I choose not to answer	I do not Agree	Somewhat Agree	Halfway Agree	Mostly Agree	Completely Agree

After the central line lab, I feel connected to clinical faculty I may work with during the clerkships.

0	1	2	3	4	5
I choose not to answer	I do not Agree	Somewhat Agree	Halfway Agree	Mostly Agree	Completely Agree

The central line lab helped me connect gross anatomy with clinical practice.

0	1	2	3	4	5
I choose not to answer	I do not Agree	Somewhat Agree	Halfway Agree	Mostly Agree	Completely Agree

The central line lab allow me to experience realistic clinical practices.

0	1	2	3	4	5
I choose not to answer	I do not Agree	Somewhat Agree	Halfway Agree	Mostly Agree	Completely Agree

During the central line lab, I felt like I was learning how to be a doctor.

0	1	2	3	4	5
I choose not to answer	I do not Agree	Somewhat Agree	Halfway Agree	Mostly Agree	Completely Agree

STUDY III – IRB Proposal

Laboratory Integration: Learning Human Anatomy through Medical Procedure School of Medicine University School of Medicine

Statement of the Problem

There is a strong movement in the medical education literature driving a transition from traditional distinctions of pre-clinical basic science training and clinical clerkship training. Medical education is moving towards greater integration between the basic sciences and clinical practices in the classroom to provide more meaningful contextual learning as well as earlier frameworks for understanding clinical practice. At the School of Medicine School of Medicine, this transition is in its early stages, and students' evaluations assert that the gross anatomy course inadequately prepares them for their clinical clerkships.

Evidence-Based Literature Review and Synthesis

Among the challenges facing anatomical teaching are the varying approaches to laboratory learning. Dissection, considered the hallmark of the biological science lab, can be performed on human cadavers or animal substitutes such as cats, and can be student-lead or replaced with prosections. Anatomy programs without dissection, either as a curricular decision or due to a lack of access, rely on electronic media, texts, and 3D models to represent the human form. Regardless of the laboratory approach, the primary indictment of anatomy courses is the tendency to emphasize a bulimic learning style. Anatomy is heavily dependent on lower-level cognitive tasks such as memorization, identification, and description (Bloom, 1956). It is understandable that courses take this road, given the enormous volume of factual knowledge in anatomical study, and its historical underpinnings as a taxonomic science. However, the anatomy laboratory has a responsibility to engage students in meaningful education models to prepare them for the life-long learning that will underpin their success as healthcare practitioners (Darda, 2010; Older, 2004).

Health professions schools also aim to develop students' clinical reasoning and procedural proficiency, and anatomical knowledge underlies these elements of safe and efficient clinical practice (Bergman, Van Der Vleuten, & Scherpbier, 2011). Anatomy also contributes to the development and retention of clinical knowledge and skills (Dangerfield et al., 2000; Fasel et al., 1999; Raftery, 2007). Despite anatomy's value, reports suggest that medical students and early career physicians do not possess sufficient anatomical knowledge (Waterston & Stewart, 2005; McKeown et al., 2003; Gupta, Morgan, Singh, & Ellis, 2008). Responding to the growing belief that medical students are not receiving sufficient training in anatomy, Bergman and colleagues' 2011 review found trends that could impair student learning, but found few articles that empirically evaluated anatomical knowledge. The authors also concluded that anatomy still lags behind other basic sciences in those practices that improve knowledge acquisition and application (learning in context, exposure to clinical practices, and vertical integration). While senior medical school students strongly believe anatomy to be relevant in their clinical practice (Moxham & Plaisant, 2007), a study of Australian medical students reported that 65% described their medical school's emphasis on anatomy as 'far too little' or 'too little,' and only 39.7% felt they would have sufficient anatomical knowledge to practice competently (Mitchell & Batty, 2009). A potential solution to the anatomical integration gap is in the gross anatomy lab.

Some medical schools and graduate medical education programs have implemented the teaching of medical procedures using human cadavers in the gross anatomy lab. Studies on procedural learning events show that medical students respond positively and place a high value on the experience (Wilson & Nava, 2010), and the learners walk away with improved confidence (Fergoson, Shareef, Burns, & Reid, 2016) and competence (Weaver, Kyrouac, Frank, & Rabinovich, 1986; Oxentenko, Ward, Pankratz, & Wood, 2003). The cadaver-based medical procedures activities satisfy the needs for learning in context, exposure to clinical practices, vertical integration, and the development of professional identity. While it seems intuitive that engaging in clinical procedures would improve academic performance, the literature lacks evidence that these procedure-based learning activities objectively improve anatomical knowledge.

Project Aims

This project will make two primary contributions to the existing literature: (1) learning outcomes data when using a procedure-based learning activity; (2) students' perceptions of professional identity and preparedness for clinical clerkships.

Aim 1: Quantitatively compare anatomical learning outcomes via immediate post-assessment and delayed post-assessment.

Aim 2: Evaluate the 1st-year medical students' perceptions of their professional identity development, engagement, and preparedness for clinical clerkships following a gross anatomy laboratory using a cadaver-based medical procedure learning module.

Project Methods

Design. Prior to the procedure module, participants will watch online videos and read a research article related to professional practices (obtaining informed consent, infection control, and the time out process verifying the patient, procedure, and patient side are correct). Participants will also undergo a pre-lab readiness assessment that will include items related to medical and anatomical knowledge, as well as perceptions of preparedness, confidence, and engagement with faculty, and formation of professional identity. In the laboratory, nineteen physician instructors will guide and supervise small groups of participants in the clinical implications, relevant anatomy, and practices related to conducting a central venous line procedure. Following the laboratory, the students will undergo a post-assessment identical to the pre-assessment. Follow-up analyses will be conducted comparing pre- and post-assessment anatomical knowledge with academic performance on neck anatomy items on the subsequent course exam.

Setting. This project will occur in the School of Medicine University School of Medicine's first-year Gross Anatomy Laboratory

Participants. The participants will be 116 first-year medical students. This intervention is being implemented as a quality improvement activity within the laboratory, and all participants will engage in the activity. However, the participants will have the opportunity to provide informed consent to allow their data to be analyzed for the study. There are no incentives for participation. Benefits include potential improvements in learning outcomes and learning engagement. The risk associated with the central line procedure is the opportunity to poke one's self with a needle. However, the procedure will be supervised and guided by a physician instructor. Additionally, the risks of the central line procedure are not greater than the risks associated with the tools used in a standard anatomical dissection.

Outcomes and measures.

- **Outcome 1 –** Learning outcomes in anatomical and medical knowledge assessed with multiple choice items developed by clinical and anatomical faculty.
- **Outcome 2 –** Students' perceptions of preparedness, confidence, faculty engagement, and professional identity formation assessed with Likert-scale statements developed by clinical and anatomical faculty.

Data analysis. Data analyses will include descriptive statistics as well as a t-test comparison between pre- and post-assessments for medical knowledge and students' perception items. Anatomical knowledge data will be analyzed using repeated measures analysis of variance (RM-ANOVA) for differences between pre-/post-assessment and the subsequent exam items on neck anatomy.

Timeline. The students will have access to the online preparatory materials for 1 week prior to the procedure lab, and will be required to complete the online readiness assessment within 48 hours prior to the procedure lab. The immediate post-assessment will be due within 24 hours following the procedure lab. The delayed assessment will take place with the gross anatomy exam 18 days following the procedure lab.

Resources and funding. Central venous catheterization kits required for the procedural demonstrations will be acquired free of charge as surplus medical supplies from the School of Medicine University Health System REMEDY program. All other aspects of the project will be supported via the School of Medicine School of Medicine Office of Curricular Affairs as part of ongoing efforts to assess and improve the medical education program.

Consent Process

Participants will be asked to complete a written informed consent prior to the study.

How much time will the prospective participant have between being approached about participating in the study and needing to decide whether or not to participate?
Students will have at least 7 days to decide whether or not they would like to participate in the survey.

Where will the consent process occur?
Consent forms will be distributed to students at in-person introduction to study, one week prior to the study, in the Trent Semans Center. Students will not be asked to sign consent at that time, though they may wish to sign at that time if they want. Students will also have opportunity to consent at the time they receive formal invitation via email invite, as the email invite will include the consent form.

What steps will be taken in that location to protect the privacy of the prospective participant?
Participants will be notified that study participation is completely voluntary and that consenting to participate (signed consent forms) may be collected at that time. If students prefer, they will have opportunity to consent at the time they receive formal invitation via email invite, as the email invite will include the consent form. Individual consent using School of Medicine email system is very private.

How much time will be allocated for conducting the initial consent discussion, including presenting the information in the consent document and answering questions, with each prospective participant?
At least 10 minutes will be allocated for students to ask questions in large group. Individual students who approach the PI with questions will have essentially unlimited time for questions.

What arrangements will be in place for answering participant questions before and after the consent is signed?
Students will be provided contact information for the study PI. The study PI will be available to answer questions at any time.
Describe the steps taken to minimize the possibility of coercion or undue

influence.
Students will be notified that study participation is completely voluntary, that participation or non-participation has no bearing on their evaluations/course grades, that the study PI is not responsible for conferring grades during their 1st year of medical school.

What provisions will be in place to obtain consent from participants who do not read, are blind or who do not read/understand English?
Not applicable (as these are conditions that would impact successful matriculation to DUSOM)

Data Collection, Management, Storage & Confidentiality

Explain how you will ensure that the subject's privacy will be protected:
DUSOM data will be maintained in secure School of Medicine-authorized survey software tools (e.g. Qualtrics), on electronic spreadsheets and word documents, and on a secure laptop. Electronic data will be kept on secure, encrypted, password-protected School of Medicine devices (e.g. laptop and/or shared drive). Identifiers associated with completed surveys will be the students' names and email addresses. Any data that is disseminated publicly will be stripped of identifying information and reported only in the aggregate.

We will ask a third party within the Office of Curricular Affairs to be the honest broker for collection of identified data (e.g. student names, student email addresses, student exam scores). This broker will strip the identifying information before analysis by the study team.

Describe how research data will be stored and secured to ensure confidentiality:
Data Collection and Security Plan:
DUSOM will be responsible for its own data collection. DUSOM data will be maintained in secure School of Medicine-authorized survey software tools (e.g. Qualtrics), on electronic spreadsheets and word documents, and on a secure laptop. Electronic data will be kept on secure, encrypted, password-protected School of Medicine devices (e.g. laptop and/or shared drive). Identifiers associated with completed surveys will be the students' names and email addresses. Any data that is disseminated publicly will be stripped of identifying information and reported only in the aggregate.

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STUDY III – Informed Consent

CONCISE SUMMARY The purpose of this research study is to determine the effectiveness of a medical procedure learning module in improving anatomical and medical knowledge in first-year medical students. Participants will review online preparatory materials related to professional practices in infection control, obtaining informed consent, and ensuring the correct procedure is being performed on the correct patient. Prior to arriving in the laboratory, participants will complete an online readiness assessment related to professional practice, anatomical knowledge, and perceptions of professional preparedness. In the gross anatomy laboratory, participants will undergo a physician-guided anatomy learning activity of a central venous line procedure. Following the learning activity, participants will complete a post-assessment to gauge changes in anatomical and medical knowledge, and perceptions of professional preparedness. Retention of anatomical knowledge will be measured by evaluating relevant items on the subsequent gross anatomy lab.

You are being asked to take part in this research study because you are a first-year medical student. Research studies are voluntary and include only people who choose to take part. Please read this consent form carefully and take your time making your decision. As the study staff discusses this consent form with you, please ask him/her to explain any words or information that you do not clearly understand. The nature of the study, risks, inconveniences, discomforts, and other important information about the study are listed below.
Please tell the study staff if you are taking part in another research study. *The PI* will conduct the study and it is funded by the School of Medicine University School of Medicine.

WHY IS THIS STUDY BEING DONE?

The purpose of this study is to evaluate the effectiveness of a medical procedure learning laboratory in the development of first-year medical student knowledge of professional practices, anatomical knowledge, and perceptions of professional preparedness. This study will contribute to the understanding of best practices in medical education.

HOW MANY PEOPLE WILL TAKE PART IN THIS STUDY?

Approximately 116 people will take part in this study at School of Medicine University School of Medicine.

WHAT IS INVOLVED IN THE STUDY?

If you agree to be in this study, you will be asked to sign and date this consent form.

- Consent to allow your pre- and post-assessment data to be analyzed.
- Consent to allow your academic data to be analyzed.

You will complete online questionnaires, before and after the learning laboratory, regarding professional practices (infection control, obtaining informed consent, and ensuring the correct patient is undergoing the correct procedure), anatomical knowledge, and perceptions of professional preparedness. Your consent to participate in this study pertains only to permitting your data to be analyzed.

HOW LONG WILL I BE IN THIS STUDY?

This study will take place over the course of 3 weeks. You can choose to stop participating at any time without penalty or loss of standing within the School of Medicine. Please contact the PI (if you would like to withdraw from this study.

WHAT ARE THE RISKS OF THE STUDY?

The risk of this study needle-poke injury during the central venous line procedure. However, this procedure will be guided and supervised by a physician instructor. Moreover, the risk of injury is not greater than using standard anatomical tools for dissection. Additionally, there is potential risk of loss of confidentiality. Every effort will be made to keep your information confidential, however, this cannot be guaranteed. *You may stop your participation in this study at any time.*

ARE THERE BENEFITS TO TAKING PART IN THE STUDY?

If you agree to take part in this study, you will receive no direct benefits. However, you may experience a more engaging learning experience. We hope that in the information learned from this study will benefit future curricular initiatives in the School of Medicine.

WILL MY INFORMATION BE KEPT CONFIDENTIAL?

Participation in research involves some loss of privacy. We will do our best to make sure that information about you is kept confidential, but we cannot guarantee total confidentiality. Your personal information may be viewed by individuals involved in this research and may be seen by people including those collaborating, funding, and regulating the study. We will share only the minimum necessary information in order to conduct the research. Your personal information may also be given out if required by law.

As part of the study, results of your questionnaires and academic data may be reported to School of Medicine University School of Medicine and its affiliates. Reviewers may include the School of Medicine University Health System Institutional Review Board, and others as appropriate.

Expiration date or event for the retention of records

The study results will be retained in your research record forever. Any research information in your medical record will also be kept indefinitely.

This information may be further disclosed by the sponsor of this study. If disclosed by the sponsor, the information is no longer covered by federal privacy regulations.

If this information is disclosed to outside reviewers for audit purposes, it may be further disclosed by them and may not be covered by federal privacy regulations.

While the information and data resulting from this study may be presented at scientific meetings or published in a scientific journal, your name or other personal information will not be revealed.

WHAT ARE THE COSTS TO YOU?

You will incur no costs by participating in this study.

WHAT ABOUT COMPENSATION?

There is no compensation for participating in this study.

WHAT ABOUT RESEARCH RELATED INJURIES?

Immediate necessary medical care is available at School of Medicine University Medical Center in the event that you are injured as a result of your participation in this research study. However, there is no commitment by School of Medicine University, School of Medicine University Health System, Inc., or your School of Medicine physicians to provide monetary compensation or free medical care to you in the event of a study-related injury.
For questions about the study or research-related injury, contact the PI.

WHAT ABOUT MY RIGHTS TO DECLINE PARTICIPATION OR WITHDRAW FROM THE STUDY?

You may choose not to be in the study, or, if you agree to be in the study, you may withdraw from the study at any time. If you withdraw from the study, no new data about you will be collected for study purposes unless the data concern an adverse event (a bad effect) related to the study. If such an adverse event occurs, we may need to review your entire medical record. Your decision not to participate or to withdraw from the study will not involve any penalty or loss of benefits to which you are entitled, and will not affect your access to health care at School of Medicine. If you do decide to withdraw, we ask that you contact the PI in writing and let him know that you are withdrawing from the study.

We will tell you about new information that may affect your welfare or willingness to stay in this study.
Your data may be stored and shared for future research without additional informed consent if identifiable private information, such as your name, are removed. If your identifying information is removed from your data, we will no longer be able to identify and destroy them.

WHOM DO I CALL IF I HAVE QUESTIONS OR PROBLEMS?

For questions about the study or a research-related injury, or if you have problems, concerns, questions or suggestions about the research, contact the PI.

For questions about your rights as a research participant, or to discuss problems, concerns or suggestions related to the research, or to obtain information or offer input about the research, contact the School of Medicine University Health System Institutional Review Board (IRB) Office.

STATEMENT OF CONSENT

"The purpose of this study, procedures to be followed, risks and benefits have been explained to me. I have been allowed to ask questions, and my questions have been answered to my satisfaction. I have been told whom to contact if I have questions, to discuss problems, concerns, or suggestions related to the research, or to obtain information or offer input about the research. I have read this consent form and agree to be in this study, with the understanding that I may withdraw at any time. I have been told that I will be given a signed and dated copy of this consent form."

____ ___________
Signature of Subject Date

____ ___________
Signature of Person Obtaining Consent Date

STUDY III – Recruiting Script

With the following survey, we ask that you participate in an MS2021-wide study. This study is particularly interested in gathering information about academic and professional learning through engaging in medical procedure-based educational activities.
This survey should take you about 15-20 minutes to complete.
Your willingness to voluntarily participate in this study would be of great assistance to us.
All survey responses will be linked to exam performance data. Once linked, the data will be de-identified and stored in the aggregate. Data will be analyzed using only quantitative approaches.
Your participation in this study is voluntary and you may withdraw at any time without prejudice or consequence. Please see attached for consent form. If you have not already completed this form, then please sign and send to me at this address.

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